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WEIBULL PARAMETER CALCULATION AND WEIBULL MONTE CARLO ANALYSIS FOR ANALYZING PARTS FAILURES IN GAS TURBINES AND OTHER EQUIPMENT

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A set of computer codes has been developed which can be used to analyze failure characteristics using a Weibull distribution. Included are codes for Weibull Parameter Calculation, Present Risk Analysis, Future Risk Analysis, Characteristic Life Calculation, and two Monte Carlo Failure Forecasting Codes providing both long and short printouts. When combined with Life Cycle Cost Analyses these codes will contribute to determination of rigorous return on investment for management decision making.

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The Naval Air Development Center (NAVAIRDEVCEN) has developed a computer-based capability to estimate the lives of engine components. There exists a need to provide both rapid (first order) as well as more accurate estimates, therefore, an interactive conceptual design code, which operates on a desktop micro-computer, has been developed as LIFER, reference (a). This document describes the WEIBULL risk computational routine (WEIBER) which can be used alone, or as an integral part of the life estimation methodology. When combined with the Navy Life Cycle Cost Program, these codes will provide a true Return On Investment (ROI) capability. These codes provide the user with the capability to analytically establish trends with a high degree of confidence in their accuracy. Such results can be used for the many decision making requirements and can be presented to higher authorities for budget justification with a high degree of confidence.

There are numerous problems that can be addressed with these computer codes, such as: evaluating several options to fix fleet problems, minimizing operating costs, maximizing performance, deciding whether to increase the life of a part or buy more spare parts, etc. These computer codes represent the analytical tools required to make such evaluations, but they must be applied with care and good engineering judgment. Like any computer tool, they can be misused through careless input of incomplete or improper data. Throughout this and other reports describing these analytical tools there will be found cautions regarding the applicability of the tools and the necessity for as good and as complete a set of input data as possible. With the proper approach to the WEIBULL risk analysis referenced herein, almost any parts failure problem can be solved within the scope of the computer codes.

The code listings in the Basic language are given in the appendix. Most of these codes were originally developed on a Radio Shack Model 4 and in the version presented here they are directly usable on an ITT XTRA. This version has also been checked out on an IBM PC, an IBM PC-XT, an IBM PC-AT, a Tandy 1000, and a Zenith PC, using the identical disk and has been found to work perfectly. Past experience has shown that problem solution is enhanced and speeded up by making small changes to these codes as dictated by the individual problem. These changes are, for the most part, in the output format and not the calculation methodology. Several examples are referenced in this report.

PROGRAM OVERVIEW

The Weibull Analysis Program is currently made up of fifteen codes, including the executive routine, "WEIBER", with its cover and introductory screens. These ccdes follow the general approach to Weibull analysis that is found in references (b) and (c) which outline the fundamental approach of the aircraft engine industry as represented by Pratt & Whitney and the General Electric Company. If at all possible, these references should be read in their entirity before using the codes of this report (WEIBER). References (d) through (g) were used to complete the understanding of general life prediction methods and make excellent reading for those interested in learning more about this area of reliability analysis.

The WEIBER executve routine code provides access to all other codes as well as the limited "HELP" routine. Currently, HELP only provides a concise description of the functions of each code and the input required to run each code. HELP also describes the output parameters that each code provides. The following paragraphs provide descriptions of all currently available codes.

SUSWEIBL, the Weibull parameter calculation code, is used to calculate the Weibull slope 'BETA' and the characteristic life 'ETA' using a statistical sample of data composed of both failures and suspended units (where suspended units are parts that are non-failed or not failed by the failure mode that is currently under consideration). Data required by the code are: (1) the total number of units in the sample population, (2) the number of failed units in the sample population, and (3) the quantity in, and age of, each group of units with the same age or operating time. The output from this code consists of: (1) BETA, (2) ETA, (3) B10 life, (4) B50 life, (5) least squares correlation coefficient, and (6) the instantaneous failure rate versus the age of the units. If BETA is known, or a good estimate is available, the option (6) code, 'ETACALC', could be used to calculate the characteristic life.

PRESRISK, the Present Risk Analysis code, is used to calculate the expected number of failures to have occurred to date over the current life of the units in the sample. The code is also useful for verifying the values of BETA and ETA by comparing answers obtained using this code with known failures in the population. Data required by the code are: (1) BETA, (2) ETA, and (3) the quantity in, and age of, each group of units with the same age. The output from this code consists of: (1) the percent in each group expected to fail,

(2) the number in each group expected to fail, and (3) the total number of expected failures for the population.

FUTRISKS, the future risk analysis code, is used to calculate the expected number of failures over a specified future time period for a population that accumulates more operating time over that time period. It is assumed that there are no repairs or new production so the failures are for the original population only and each part can fail only once. A more complex analysis, where parts are repaired and returned to service, is available in the Monte Carlo risk analyses, options 5, 6 and 11. Data required by the code are: (1) BETA, (2) ETA, (3) the number of months into the future that the analysis will cover, (4) the average monthly operating hours (or cycles or other time measurement) per part over the time period, and (5) the quantity in, and age of, each group of parts with the same age. The output from this code consists of: (1) the percent in each group expected to fail, (2) the number in each group expected to fail, (3) the cumulative count of failures, and (4) the total number of expected failures for the population.

WEIBRISK, a Monte Carlo Weibull failure analysis code, is used to forecast numbers of failures as well as the failure times in terms of operating hours or cycles. It is a complex code that makes thousands of calculations in each problem solution and keeps track of failures as they occur. The code also computes averages per iteration and per engine. It is extremely accurate when the correct Weibull parameter data is input and is capable of providing sensitivity analyses when precise Weibull data is difficult to obtain, such as early in an engine program when there have been few or no failures. Data required by the code are: (1) BETA, (2) ETA, (3) the quantity in, and age of, each group of parts with the same initial operating time, (4) the total number of units in the population, (5) the number of months into the future that the analysis will cover, (6) the average operating hours (or cycles, etc.) per month per part over the total time of the analysis, (7) the inspection interval at which, if reached before a failure occurs, all parts are made good-as-new or zero-timed, (8) the number of failure modes in the analysis, and (9) the engine name from which the parts come. Note that BETA and ETA must be furnished for each failure mode. It should also be noted that large numbers of parts and/or failure modes will greatly increase the running time (computer time). The output from this code consists of: (1) failure times, (2) running count of time on each engine, (3) subsequent failure time, (4) the number of failures per engine or part, (5) identification of the failure mode, (6) the average number of failures per engine or part per iteration, (7) the cumulative failures per engine, and (8) the average number of failures for all engines or parts over the total number of iterations. The number of iterations in the analysis can be varied to any number desired. It is strongly suggested that a minimum of ten iterations be used.

SHRTWEIB, a Monte Carlo Weibull failure analysis code with a short printout, is a code that is almost identical to the previous code, WEIBRISK, except for the amount of hard copy output. In order to speed up the analysis, only numbers of failures are output while failure times by failure mode are suppressed. This code is very useful for the case where the dominant failure mode has been determined and the primary concern is the number of failures. It is also useful when time is critical and the calculation of the number of failures will allow some initial decisions to be made. With this code, many more engines or parts may be analyzed in a given amount of computer time relative to WEIBRISK and the amount of paper output generated is significantly less.

ETACALC is a code to calculate the characteristic life ETA when BETA is known for the failure mode and based on a statistically valid number of failures. Very accurate failure data is required to result in an accurate calculation of ETA using this code. Data required by this code are: (1) BETA, (2) the total number of failures for which data is available, and (3) data pairs consisting of the number of failures and operating times at the failure(s). The output from this code is the calculated value of the characteristic life, ETA.

CNFINTBE is a code to calculate upper and lower confidence bounds for both Beta and Eta as well as time to first failure. These calculations can be made for confidence levels of 0.90, 0.95, or 0.99. These upper and lower limits are indications of the accuracy one can expect from the many calculations that can be made from these codes. As higher values of confidence levels are chosen, the upper and lower bounds move farther apart.

RELIABTY. This code is used to calculate the reliability of a part at any time based on the values of Beta and Eta. The confidence interval may then be calculated for the value of reliability at confidence levels of 0.9, 0.95, and 0.99. The probability of failure is also presented. As in the case of the previous code, the upper and lower bounds move farther apart as the confidence level is chosen to be a higher value.

BETAHIST. This code prints a hard copy of a list of probable values (or ranges of values in some cases) of the Weibull slope Beta for some common failure modes in gas turbine components or parts. While these historical trend values should not be taken to be absolute, they represent reasonable starting values, especially for performing sensitivity or "what-if" analyses.

<u>**PWAWEIBL**</u>. This code is similar to the SUSWEIBL code, number 1, except that it can provide the values of Beta and Eta which maximize the 'likelihood' of obtaining the observed data. There may be cases where these values may differ from those obtained in code number 1 or other codes that may be available. In most cases, however, they are close enough to not impact the final results to a great degree. If there is a concern over accuracy it is recommended that the data be run through both codes to establish sensitivities.

<u>**BIGWEIBL**</u>. This code is especially designed to handle up to 1100+ parts in a Monte Carlo analysis. It has been optimized for large numbers of parts and should be used only after the dominant failure mode has been determined. No more than one failure mode should be analyzed at one time when the quantity of parts nears the maximum since the memory available to the basic language will most likely be exceeded. The input is the same as for the previously described WEIBRISK and SHRTWEIB Monte Carlo analyses, (4) and (5), but the output is limited to that of of code (5). Only the total failures are given per iteration along with the averages.

<u>**WEIBAYES**</u>. This code is for use when there is insufficient failure data to calculate the Weibull slope Beta and the characteristic life Eta with codes (1) or (10). This code requires that a best estimate be made of the failure mode and hence the Weibull slope Beta. The BETAHIST code (9) should be used for guidance as necessary. It is also required that the characteristic life be known or estimated using the ETACALC code (6) which is the true Weibayes estimate of 'ETA'. These values form the input for this code which then calculates the appropriate life of the part in question.

<u>**ZOFAILSB**</u>. This code calculates the number of engines/parts that must be tested without failure in order to demonstrate that a given failure mode has been either eliminated or substantially improved. Inputs required are (1) Weibull slope Beta, (2) characteristic life Eta, and (3) an estimate of a reasonable amount of test time, recognizing that at least three parts or more must each be tested for that amount of time. The code allows a second and third test time estimate to be made (or more if necessary) and also provides for an alternate method of test plan formulation. The test plan is output in terms of a sample size, each of which must be tested for a given number of hours (or cycles) without failure in order to demonstrate a significant improvement in life.

<u>**NZFTESTP**</u>. This code is similar to the previous code except that it calculates a test plan that allows for

failures. Here the goal is to devise a test plan to demonstrate the achievement of a given improvement in a part's characteristic life. The test is passed if all parts are run for a specified number of test hours (or cycles) with no more than the calculated number of failures. Input consists of (1) the current characteristic life, (2) the characteristic life with an improved part or fix, (3) the Weibull slope BETA for the failure mode, and (4) a reasonable estimate of test hours for each test article. Output consists of a sample size, the number of test hours for each part in the sample, and the number of failures allowed for a successful test.

PROGRAM DESCRIPTION AND OPERATION

PROGRAM WEIBER

WEIBER is the WEIBULL Executive Routine which provides access to all other codes and the HELP routine. This code is entirely interactive and menu driven. When WEIBER is first activated, those familiar with its operation can go right to the desired code to calculate the parameters of interest. Those with less familiarity should choose the menu or HELP. Choosing the menu still allows one to go to help if desired, directly from the menu. The menu gives the user the choice of selecting any of the options by name and number. An option is chosen by inputting the option number. The chosen code next appears with instructions on how to proceed. Always be sure to follow instructions explicitly because format is critical for most input.

There are currently fourteen options available with room for four more. Future codes which are being considered at the present are those to utilize Weibull "Thorndike" charts, treat shifting Weibulls, and account for curved Weibulls. In addition, data bases for Weibull parameters will be established as the codes are used for solving more and more problems. These and other options will be added as they become necessary in the ongoing process of analysis. The current fourteen options will be described in more detail and sample solutions will be presented to illustrate their fundamental capability. Some of the options exist in several versions other than those presented. These other versions were generated for special case analyses and will not be presented here since they are not general enough to be of wide interest.

1. SUSWEIBL is the SUSPENDED WEIBULL code which is used to calculate values of the Weibull slope (BETA) and the characteristic life (ETA). Actual failure data is used as well as data from parts in the population which have not failed, or have failed in another failure mode. For

example, consider a population of six turbine disks which have all been tested to failure. Figure 1 shows the first screen of the SUSWEIBI code which asks for the input data. First, the total number in the sample is required, along with the number that have failed. Secondly, the distribution of failures is required. This data is input in the format of data statements and requires line numbers for the BASIC code. Figure 2 is a sample of such an input. Note that in each case there is a line number followed by the requested data. The exact line number as shown must be used. All computers have limits for the length of data lines so more lines may be needed. Use consecutive line numbers if more lines are required, starting with 8911 and not exceeding 9000. As currently configured, only ten data pairs can be entered. To enter more than ten data pairs, add dimension statements as follows in lines 150 and 151:

```
150 DIM T(100)
151 DIM F(100)
```

This will allow a total of 100 data pairs to be used.

Note that the values F1, F2, F3, etc., are the cumulative count of the failures and that there must be as many values as the number K entered in line 8800. The cumulative count data are always entered as increasing numbers which are consecutive. See line 8910 in figure 2. In cases where the entire population has NOT failed there will be suspended data. For example, there may have been only five failures out of the population of six. In the illustrated case of Figure 2, this may have been the disk with 950 hours, or disk number 4. The data line would then be:

```
8910 DATA 780,1,820,2,910,3,1050,5,1050,6
```

Note that the fourth disk with 950 hours has been omitted, or suspended, but that everything else is the same as in figure 2. The values of Beta and Eta will be slightly different for five out of six failures than for all six failing, as they should be. Always enter the data in ascending order of age to failure, omitting unfailed parts or parts failed in other failure modes. This same data is used to create a histogram of failures.

The sample solution presented later in this document shows a sample of the output screens using an input of six out of six failures. If a Weibull plot is desired it may be plotted using the data presented (Cumulative Percent Failed versus Time to Failure). Also shown on the screens are Beta, Eta, B10 and B50 lives, and the least squares correlation coefficient. The Weibull parameters may be verified by plotting the Weibull data and graphically determining the same values. Additional data shown on the

```
    SUSPENDED WEIBULL PARAMETER CALCULATION PROGRAM (GEN ELEC CO)
     AS IMPROVED BY CODE 6052, NAVAIRDEVCEN, WARMINSTER, PA 18974


DATA INPUT ------ TYPE IN THE FOLLOWING :

8800 DATA N,K

     WHERE N = THE TOTAL NUMBER IN TH SAMPLE AND
           K = THE NUMBER OF FAILURES

8910 DATA T1,F1,T2,F2,T3,F3,...,ETC.

     WHERE T1 IS THE AGE IN HOURS OF THE FIRST FAILURE
           F1 IS THE CUMULATIVE COUNT OF THE FIRST FAILURE
           T2 IS THE AGE IN HOURS OF THE SECOND FAILURE
           F2 IS THE CUMULATIVE COUNT OF THE SECOND FAILURE, etc

USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA.
WHEN THE LAST DATA IS ENTERED, INPUT <RUN 2100> TO CONTINUE.
Break in 2000
Ok
```

FIGURE 1   SCREEN 1   SUSWEIBL

```
8800 DATA 6,6
8910 DATA 780,1,820,2,910,3,950,4,1050,5,1050,6
```

FIGURE 2   SUSWEIBL INPUT SAMPLE

last screen is the value of the instantaneous failure rate versus the age of the parts. Note that all of the above output values will change if either more or fewer than six failures are used.

2. **PRESRISK** is the PRESent RISK analysis code which is used to calculate the number of units that should have failed by the present time, or, the expected failures to date based on the current operating times. This code is very useful in verifying the values of Beta and Eta that are used, knowing the actual number of failures to date and comparing them with the calculated number of failures. Figure 3 shows the first screen of the PRESRISK code which asks for the input data. The first data required are the values of Beta and Eta for the given failure mode. This input is entered as a data statement and therefore requires a line number (4000). The next input are data pairs consisting of the number of parts that all have the same current operating time and the value of that common operating time. These data are also entered as a data statement using the line number 4040. Again, as many data pairs as necessary should be used as long as it is consistent with the line length allowed by the computer being used. The current code allows for ten data pairs but this may be increased by adding dimension statements as in SUSWEIBL. For example:

```
12 DIM N(100)
13 DIM T(100)
```

This will allow a total of 100 data pairs to be used. Figure 4 is a sample of such input and consists of five data pairs representing a total of twenty-five parts. It can be seen that there are five categories of operating time and that there are five parts in each time category. Additional data pairs can be input by using additional DATA lines starting with program line 4041 and not exceeding line 4999. Note that data is entered in ascending order of operating time.

Data pairs should be formulated such that the distribution represented by all the data pairs is a good representation of the real life distribution. There can be as many as one data pair for every part, but this usually becomes unwieldy when there are many parts to be considered. It is not necessary for the data pairs to represent exact multiples of the same size, such as 5, 10, 20, 100, or 1000. The number of parts in each data pair can be the same or each one can be entirely different and completely independent. The distribution should be as representative and complete as possible to yield the most accurate results.

The last input data is that of figure 5. Inputting the number of data pairs entered is necessary for the code to

```
                    PRESENT RISK ANALYSIS
          NAVAL AIR DEVELOPMENT CENTER, CODE 6052
                    WARMINSTER, PA 18974
                         26  FEB  86

DATA INPUT ------------ ENTER THE FOLLOWING :
4000 DATA B,H

          WHERE B = THE WEIBULL SLOPE 'BETA'
          AND   H = THE CHARACTERISTIC LIFE 'ETA'

4040 DATA N1,T1,N2,T2,...,etc.

          WHERE N1 IS THE NUMBER OF UNITS AT TIME T1
                T1 IS THE OPERATING TIME OF UNITS N1
                N2 IS THE NUMBER OF UNITS AT TIME T2
                T2 IS THE OPERATING TIME OF UNITS N2

USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA.
WHEN THE LAST DATA IS ENTERED, INPUT <RUN 75> TO CONTINUE.
Break in 70
Ok
```

FIGURE 3 SCREEN 1 PRESRISK

```
          4000 DATA 3,2000
          4040 DATA 5,100,5,200,5,300,5,400,5,500
```

FIGURE 4 PRESRISK INPUT SAMPLE

```
INPUT THE NUMBER OF DATA PAIRS JUST ENTERED? 5

INPUT THE ENGINE AND/OR COMPONENT NAME? TF
```

FIGURE 5 PRESRISK INPUT

```
                PRESENT RISK ANALYSIS
             NUMBER OF FAILURES EXPECTED
          TO HAVE OCCURRED BASED ON CURRENT
                   OPERATING TIMES

                         TF


DATA PAIRS USED:         (NO. OF UNITS, OPERATING TIME)

5, 100, 5, 200, 5, 300, 5, 400, 5, 500,

NO. UNITS           TIME          %FAIL               NO. FAILS

     5              100       1.250506E-04          6.252527E-04
     5              200       9.95103E-04           4.997552E-03
     5              300       3.369331E-03          1.684666E-02
     5              400       7.968068E-03          3.984034E-02
     5              500       1.550353E-02          7.751763E-02

TOTAL FAILURES = .1398274

VALUE OF WEIBULL SLOPE BETA IS 3

VALUE OF CHARACTERISTIC LIFE ETA IS 2000
```

FIGURE 6 PRESRISK OUTPUT SCREEN

properly account for all data pairs. This number is used in a counting loop to assure all failures are calculated.

The output screen is shown in figure 6. In addition to giving the number of failures for each data pair, the total failures are given for all data pairs. Also, the inputs are presented such that a record is available to identify the case analyzed. The current PRESRISK code automatically gives a hard copy printout that duplicates the output screen. This can be suppressed by eliminating all lines in the code that start with LPRINT. It is NOT recommended that this be done except when a printer is not available or when the available printer is not working. In such cases the code will hang up if the LPRINT instructions are not eliminated. Do NOT save the code with the deleted LPRINT lines using the same name (PRESRISK) or the hard copy version will be lost.

3. FUTRISKS is the FUTure RISKS analysis code which is used to calculate the expected number of failures over the next user defined time period, such as 12, 15, 30, or 36 months. This future time period is always specified in months and may be any value as required. Only one failure mode can be examined at a time but the code runs very fast and can be repeated as many times as necessary to cover as many failure modes as one desires in a very short period of time. Figure 7 shows the first screen of FUTRISKS which requests the input data. The first data items to be input are BETA and ETA for the failure mode of interest, just as in the previous code, PRESRISK. Again, this is entered as a data statement and requires a line number, which in this case is 4000. The next input required is the number of months into the future that the analysis is to cover, along with the average utilization rate in operating hours per month. These input data items are separated by a comma as are BETA and ETA. Note that cycles, time at maximum power, time at specified temperature, afterburner lights, or any other age measurement may be used in place of operating hours as long as BETA and ETA are determined using the same parameter.

The last data to be input are data pairs consisting of current operating time (or cycles, etc.) preceded by the number of units or parts having the same operating time. Again, all values are separated by commas. As many data pairs as necessary may be entered but it should be kept in mind that, as the number of data pairs grow, the computing time lengthens. While the computation time lengthens, the computer code is still relatively fast with large numbers of data pairs. There is currently a limit of 41 data pairs in the code. If more data pairs are to be used, change the existing dimension statements to the number desired. For example:

```
                         FUTURE RISK ANALYSIS


DATA INPUT ------------- ENTER TH FOLLOWING :
4000 DATA B,H
          WHERE B = THE WEIBULL SLOPE 'BETA'
                H = THE CHARACTERISTIC LIFE 'ETA'

4040 DATA MOS,UTR
          WHERE MOS IS THE NUMBER OF MONTHS AT TIME T1
                UTR IS THE MONTHLY UTILIZATION RATE

4049 DATA N1, T1, N2, T2,..., etc.
          WHERE N1 IS THE NUMBER OF UNITS AT TIME T1
                T1 IS THE OPERATING TIME OF UNITS N1
                N2 IS HTE NUMBER OF UNITS AT TIME T2
                T2 IS THE OPERATING TIME OF UNITS N2, etc.

USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA.
WHEN THE LAST DATA PAIR IS ENTERED, INPUT <RUN 250> TO CONTINUE.
Break in 230
Ok
```

FIGURE 7 SCREEN 1 FUTRISKS

```
4000 DATA 6.557812,2741.127
4040 DATA 12,80
4049 DATA 54,400,81,500,54,600,162,700,54,800,189,900,270,1000,
216,1100,270,1200,243,1300,189,1400,135,1500,81,1600,54,1700
```

FIGURE 8 FUTRISKS INPUT SAMPLE

```
290 DIM N(100)
300 DIM T(100)
```

These changes will allow a total of up to 100 data pairs to be input. One can always input fewer data pairs than allowed by the dimension statements, but never more. Figure 8 is a sample of the input required by FUTRISKS and consists of 14 data pairs representing 2052 parts. Note that the operating times are equally divided into increments of 100 with an initial value of 50 hours. At times of 1750 and 1950 the number of parts are 0 (zero). This is an indication that the input was derived from a distribution of average numbers of parts versus operating time, or a histogram. Note that the data is entered in ascending order of operating time. Data pairs for FUTRISKS should be as accurate as possible and obviously as complete as possible. If there are zero parts for a given class interval (time period) of operating time, then a zero should be entered and it should count as a data pair. Since the last input is the number of data pairs it is important to count all data pairs, even those with zero parts.

The output screen is shown in figure 9. In this figure the first and second columns are the numbers of parts and the operating time at the end of the future time of the analysis. These are data pairs corresponding to the future time for which the number of failures is desired. The third and fourth columns are the percent failure for each future time data pair and the corresponding number of failures. The last column has the cumulative number of failures for each future data pair. The last item shown is the total number of expected failures for the total population over the total accumulated operating time of the analysis. The current FUTRISKS code automatically gives a hard copy printout that duplicates the output screen. This can be suppressed by eliminating all lines in the code that start with LPRINT. It is recommended that this NOT be done unless there is no printer available. In no case should one save the code with deleted LPRINT lines on the original disk using the same name (FUTRISKS) or the hard copy version will be lost.

4. WEIBRISK is the most comprehensive of all the codes available through WEIBER. It is a completely automatic code to calculate the results of a Monte Carlo analysis; it can produce a very substantial amount of output. Use of this code can easily exceed the memory capacity (RAM) of microcomputers with 64K or less available to BASIC. If such is the case, the problem must be broken up into smaller parts, each part must be run separately, and the results then combined to form the overall result. The code is used to forecast the number of failures as well as the time for each failure. Problems can be solved with multiple failure modes where the analysis must determine the mode of failure

FUTURE RISK ANALYSIS
FORECASTED FAILURES OVER THE NEXT 12 MONTHS TIME
UTILIZATION RATE IS 80 HOURS PER MONTH

TJ

MO. UNITS	TIME	% FAIL	NO.FAILS	CUM FAILS
54	1360	0.01004	0.54191	0.54191
81	1460	0.01592	1.28990	1.83181
54	1560	0.02446	1.32075	3.15255
162	1660	0.03648	5.90921	9.06177
54	1760	0.05296	2.85973	11.92150
189	1860	0.07499	14.17324	26.09474
270	1960	0.10372	28.00345	54.09819
216	2060	0.14024	30.29192	84.39011
270	2160	0.18550	50.08423	134.47430
243	2260	0.24008	58.33913	192.81350
189	2360	0.30403	57.46207	250.27550
135	2460	0.37665	50.84838	301.12390
81	2560	0.45633	36.96305	338.08700
54	2660	0.54049	29.18628	367.27320

TOTAL FAILURES = 367.2732

FIGURE 9 FUTRISKS OUTPUT SCREEN

that causes each failure. This is done over an extended future time and is always accomplished a number of times in order to fulfill the requirements of the Monte Carlo analysis, generally 10 times or more. It is important to recognize that the analytical procedure will calculate the time to failure for all failure modes and then select the one with the shortest time to failure as the mode of failure. This is done for all engines until the total specified future time has been covered. At failure, the engine is assumed to have all modes of failure brought to zero time (good-as-new) by either replacing the part or by inspection and certification that the part will be suitable until the next inspection is due.

A typical problem could involve as many as 20 or more engines with 4 or more failure modes and with an analytical time period running as long as ten to twenty years, operating at an average of 25 to 60 hours per month. Such an analysis, performed ten times, would involve many thousands of calculations and mean keeping track of possibly hundreds of failures. It requires calculating the time to fail for each failure mode, determining which is the first mode to cause failure, and then recalculating the failures until the specified future time has elapsed. This would be done at least ten times for each engine until reasonable statistical averages can be determined.

Figures 10 and 11 show the first two screens which are introductory in that they tell what capability the code has, the required inputs, and the necessity of using the correct input format. Figure 12 is the first input screen and requests the input of BETA's for all failure modes. Also shown is a sample line input for BETA so there is no question about format. The next screen is the input for ETA's, figure 13, which also shows a sample line of input for clarity. The next input screen, figure 14, is for data pairs consisting of the number of engines with the least number of initial operating hours followed by a comma and then the corresponding number of operating hours. This data pair is followed by a comma and the next data pair of engines having the next least number of operating hours, a comma, and then that corresponding number of operating hours, and so on until all engines have been accounted for along with their initial operating times. If the initial time is zero for any engines then a zero must be input for that engine or group of engines. Again, a sample line is shown for clarification.

The next input screen, figure 15, is a series of input questions which must be answered with numbers. Items requested are: the number of data pairs entered, the total number of engines, the number of months the analysis is to cover, the average utilization rate (in flight hours per month) of the engines, the inspection interval (or maximum

WEIBULL RISK
A MONTE CARLO SIMULATION

THIS PROGRAM PROVIDES THE CAPABILITY TO CALCULATE THE NUMBER OF FAILURES FOR SEVERAL DIFFERENT PARTS IN AN ENGINE OVER A USER SPECIFIED TIME PERIOD. UP TO 25 ENGINES CAN BE ANALYZED WITH SCHEDULED INSPECTIONS WHERE THE PARTS CONSIDERED ARE BROUGHT TO ZERO-TIME, i.e. ARE MADE GOOD-AS-NEW.

INPUTS CONSIST OF: NUMBER OF ENGINES; TIME SINCE LAST INSPECTION; ANALYTICAL TIME PERIOD; FLIGHT HOUR UTILIZATION RATE; TIME BETWEEN INSPECTIONS, INITIAL TIME ON ENGINES; WEIBULL PARAMETERS (BETA & ETA); and ENGINE DESIGNATION.

OUTPUT CONSISTS OF: TOTAL ENGINE FLIGHT HOURS; CUMULATIVE FLIGHT HOURS; TIME TO FAIL FOR EACH MODE; and TOTAL NUMBER OF FAILURES BY ITERATION.

TO CONTINUE INPUT 1 AND <ENTER>. TO QUIT INPUT -1 AND <ENTER>.
YOUR CHOICE? 1

FIGURE 10 SCREEN 1 WEIBRISK

THIS IS THE DATA INPUT SECTION OF THE WEIBULL RISK CODE.

YOU WILL BE ASKED TO INPUT VARIOUS DATA IN A GIVEN FORMAT.

THE FORMAT IS CRITICAL SO FOLLOW INSTRUCTIONS CAREFULLY.

TYPE 1 <ENTER> TO INPUT DATA. TYPE -1 <ENTER> TO QUIT.

FIGURE 11 SCREEN 2 WEIBRISK

```
NOW TYPE THE FOLLOWING :

25800 DATA BETA(1),BETA(2),...,BETA(J)
          WHERE BETA(1) IS THE WEIBULL SLOPE FOR THE FIRST MODE
          OF FAILURE, BETA(2) IS THE WEIBULL SLOPE FOR THE SECOND
          MODE OF FAILURE, AND SO ON UNTIL THE NUMBER OF BETA'S
          CORRESPOND TO THE INTEGER FOR THE NUMBER OF FAILURE
          MODES. SEPARATE BETA'S WITH COMMA'S.

AFTER THE LAST BETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 21300'
AND <ENTER>.
Break in 21200
Ok
```

FIGURE 12 WEIBRISK INPUT SAMPLE SCREEN 1

```
NOW TYPE THE FOLLOWING:

25900 DATA ETA(1),ETA(2),...,ETA(J)
          WHERE ETA(1) IS THE CHARACTERISTIC LIFE FOR THE FIRST
          MODE OF FAILURE, ETA(2) IS THE CHARACTERISTIC LIFE
          FOR THE SECOND MODE OF FAILURE, AND SO ON UNTIL THE
          NUMBER OF ETA'S CORRESPOND TO THE INTEGER FOR THE
          NUMBER OF FALIURE MODES. SEPARATE ETA'S WITH COMMA'S.

AFTER THE LAST ETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 22400'
AND <ENTER>.
Break in 22300
Ok
```

FIGURE 13 WEIBRISK INPUT SAMPLE SCREEN 2

```
NOW TYPE THE FOLLOWING :

26000 DATA N1,T1,N2,T2,...,etc.
          WHERE N1 IS THE NUMBER OF ENGINES AT TIME T1
                T1 IS THE OPERATING TIME OF ENGINES N1
                N2 IS THE NUMBER OF ENGINES AT TIME T2
                T2 IS THE OPERATING TIME OF ENGINES N2, etc.

USE ADDITIONAL LINES AS NEEDE TO ADD MORE DATA.
WHEN THE LAST DATA PAIR IS ENTERED, TYPE 'RUN 23400' AND <ENTER>.
Break in 23300
Ok
```

FIGURE 14 WEIBRISK INPUT SAMPLE SCREEN 3

```
NOW INPUT THE NUMBER OF DATA PAIRS JUST ENTERED.? 1

INPUT THE TOTAL NUMBER OF ENGINES IN THE SAMPLE - NOT OVER 25.? 5

INPUT THE NUMBER OF MONTHS THAT THIS ANALYSIS WILL COVER, i.e.,
36 FOR THREE YEARS.? 36

NEXT, INPUT THE OPERATING HOURS PER MONTH (AVERAGE) OVER THE TIME
PERIOD OF THIS ANALYSIS.? 60

INPUT THE INSPECTION INTERVAL FOR THE ENGINE OF THIS ANALYSIS.?
2000

INPUT THE NUMBER OF FAILURE MODES OF THIS ANALYSIS.? 1

INPUT THE ENGINE DESIGNATION.? TP

LASTLY, INPUT ANY NUMBER BETWEEN -32768 AND + 32767 TO SEED
RANDOM NUMBER GENERATOR. USE A DIFFERENT NUMBER FOR EACH
ANALYSIS.? 9376
```

FIGURE 15 WEIBRISK INPUT SAMPLE SCREEN 4 operating time), the number of failure modes input, and the engine designation. All of these are important in that they serve as counting limits or analysis boundaries. It is important to understand that if no failure occurs before any engine accumulates the number of operating hours equal to the inspection interval, that engine is assumed to be inspected and either repaired or certified as capable of going another inspection interval in operating hours. In other words, the engine is zero-timed (or equivalently certified) with regard to the failure modes of the analysis. For the next increment of operating time the engine is starting out at zero time regardless of whether it has failed and been repaired or has been inspected and certified capable of reaching the next inspection without failure.

Figures 16 through 18 are the series of output screens. The first data shown are the inputs such that the output can always be identified with regard to the specific case run. Following this initial output is the data for each engine grouped by iteration number. In this case ten iterations were run but only the first three are presented. The time to failure is given for each failure mode and all failure times are compared to the inspection interval. If one or more of the failure times are less than the inspection interval, then there is an indication of a failure. Otherwise the indication is for no failure and the engine goes to inspection. If there were one or more failures the lowest number of operating hours, or first failure time, is chosen to be the current failure time of the engine. If there is no failure then the operating time of the engine is taken to be the inspection interval. The code accounts for initial time when it makes its first calculations on an engine and then keeps track of operating time as it accumulates, up to the total time of the analysis. From the second calculation on, the new current time will be the old current time incremented by the time to first failure or the inspection interval, whichever is appropriate. Failures are accounted for and a running total is maintained for each iteration as well as for each engine in each iteration. Unfortunately, the number of failures in each failure mode is lost in the sorting process for determining the first, or lowest, time to failure. It is possible to read the hard copy output and to determine the number of failures attributable to each failure mode.

Generally, a total of at least ten iterations will be run and averages calculated. The number of iterations should be checked, at least initially, since the code may have been furnished with a sample case that is fixed at three iterations. This is so that the sample will run reasonably fast for illustrative purposes. The averages presented in the output are: the average number of failures per iteration and the average number of failures per engine per iteration. Also presented is the total number of failures for each iteration. Until the number of failures per failure mode is added, one can always go back over the hard copy output and determine which failure mode is responsible for each failure. Unless there are a vast number of engines analyzed over a very long time period, this manual effort is relatively simple and fast. It is, however, readily apparent that there is a great deal of data generated by this code, even when there are only a few engines and a few failure modes.

5. **SHRTWEIB** and its variations are reduced output versions of WEIBRISK for use where there are many engines and several failure modes. While all the calculations and concepts of the Monte Carlo analysis are exactly the same, the amount of data output is greatly reduced. Since the output is reduced, the flexibility is also reduced. If there are many engines involved, say 250 engines and multiple failure modes, it is likely that one would be interested in first knowing the number of failures to expect. If this is the case then this is the code to use since almost all of the output is suppressed and only the final tabulations of averages and total failures is output. If there is a need for failure modes identification and failure times, it is possible to output all these values while omitting most of the explanatory words normally output by WEIBRISK. This is done by adding PRINT or LPRINT statements to the BASIC program as required by the desired data to be output.

The input screens are identical to those of WEIBRISK and will not be repeated here. The output screens are very limited. Figures 19 and 20 illustrate a case in which failure times and failure modes are not required. These figures show the SHRTWEIB output screens for the same case as show for WEIBRISK (figures 16 through 18). Only the summaries of each data pair are shown in the output, along with the input data to be sure that the particular case can be identified. The totals are kept per iteration as in WEIBRISK and the summary at the end is exactly the same as the WEIBRISK summary.

This code has been used in many different versions, each one adjusted for a particular problem application. SHRTWEIB is basically a short version of WEIBRISK and is virtually identical except for the output format. Knowing this , it is easy to see why there can be so many variations, each one called SHRTWEIB. Currently there are two main versions, SHTWEIB1 and SHTWEIB2. Only one has been presented here in the interest of brevity and because it is so simple to make any necessary change in output format. Anyone with a fundamental knowledge of the Basic language could make the necessary modifications to SHRTWEIB to fit a specific problem. Keep in mind that it may be more prudent

WEIBULL RISK ANALYSIS A MONTE CARLO SIMULATION - WEIBRISK1 ENGINE: TP BETA VALUES: 3.5 ETA VALUES: 1741 DATA PAIRS: NO. ENGS. INIT. TIME 5 100

FIGURE 16 WEIBRISK OUTPUT SCREEN 1

MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS 2160 HRS.
INSPECTION INTERVAL FOR THIS ANALYSIS IS 1500 HOURS
TIME DURATION OF THIS ANALYSIS IS 36 MONTHS
UTILIZATION RATE IS 60 HOURS PER ENGINE PER MONTH

FIGURE 17 WEIBRISK OUTPUT SCREEN2

```
***************** DATA PAIR NUMBER 1 *****************

               * * * ITERATION NUMBER 1 * * *

                         ENGINE NUMBER 1
1402.271
TIME ON ENGINE IS 1402.271
1585.924
TIME ON ENGINE IS 2160
CUMULATIVE FAILURES FOR THIS PAIR ARE 1
NUMBER OF  FAILURES FOR ENGINE 1 = 1

                         ENGINE NUMBER 2
1378.449
TIME ON ENGINE IS 1378.449
1185.871
TIME ON ENGINE IS 2160
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 2
NUMBER OF FAILURES FOR ENGINE 2 = 1

                         ENGINE NUMBER 3
2131.911
TIME ON ENGINE IS 1500
1039.275
TIME ON ENGINE IS 2160
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 1
NUMBER OF FAILURES FOR ENGINE 3 = 0

                         ENGINE NUMBER 4
1340.697
TIME ON ENGINE IS 1340.697
2215.43
TIME ON ENGINE IS 2160
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 2
NUMBER OF FAILURES FOR ENGINE 4 = 1

                         ENGINE NUMBER 5
1297.056
TIME ON ENGINE IS 1297.056
1505.346
TIME ON ENGINE IS 2160
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 3
NUMBER OF FAILURES FOR ENGINE 5 = 1


TOTAL FAILURES ITERATION NUMBER 1 = 3
```

FIGURE 18   WEIBRISK OUTPUT SCREEN 3

to modify WEIBRISK if the final configuration will be closer to that output.

6. ETACALC is a short code which will calculate the characteristic life (ETA) when the value of BETA is known or the failure mode is known and a 'good approximation' of BETA is available. Figure 21 is the input screen which first calls for BETA and then the number of failures for which failure data is available. Such data makes up the next line of input and consists of alternate values of the number of non-failed parts in the sample and the operating time on these parts. Again, this is data from a histogram of the sample population. If there were no failures, the value of 'T' should be input as one (1). This assumes that there is a failure imminent and therefore gives a conservative, or lower, value of ETA. Zero cannot be used since it would result in a 'division by zero' error. It is also required to input the number of data pairs entered for use as a counting reference.

For reference purposes, the output screen of figure 22 presents the data pairs entered and used as well as the calculated value of ETA. The value of BETA used in the calculation is also presented. This code runs very fast and is extremely useful in calculating the sensitivity of ETA against the value of BETA or the number of failures. For each value of BETA input there will be a different value of ETA. If the failure mode is known one can be reasonably sure that BETA will fall between the limits that are historically typical for that failure mode. For example, low cycle fatigue historically has a value for BETA that lies between 2 and 5. While there are no guaranteed values or ranges, there are historical trends that are reasonable starting points when there is a lack of detail about specific failures.

7. CNFINTBE & CNFINTFF are two codes that have been grouped together for convenience. The first code calculates the confidence interval, or range of expected values, for both Beta and Eta. The user chooses the confidence level (0.90, 0.95, or 0.99) desired as well as the values of Beta and Eta. These are input in response to specific prompts on the screen. The last prompt asks for the number of failures that were used to calculate these vales of Beta and Eta. Figure 23 shows the input for this code. Finally, the ranges of expected values of these parameters are given and are shown in figure 24 along with the input values and the chosen confidence level. These ranges, or confidence intervals, are measurements of precision in estimating the parameters. The confidence interval almost always contains the input value of the parameter and the magnitude of the range is an indication of how far from the true value an estimate of Beta or Eta might deviate. Strictly speaking, this methodology applies only to the case where all units or

WEIBULL RISK ANALYSIS
A MONTE CARLO SIMULATION
SHRTWEIB2

ENGINE: TP

BETA VALUES:
3.5

ETA VALUES:
1741

DATA PAIRS:

NO. ENGS.	INIT. TIME
5	100

MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS 2160 HRS.

INSPECTION INTERVAL FOR THIS ANALYSIS IS 1500 HOURS

TIME DURATION OF THIS ANALYSIS 36 MONTHS

UTILIZATION RATE IS 60 HOURS PER ENGINE PER MONTH

FIGURE 19 SHRTWEIB OUTPUT SCREEN 1

```
****************** DATA PAIR NUMBER 1 ******************



AVERAGE NUMBER FAILURES 10 ITERATIONS = 2.1

NUMBER OF FAILURES IN ITERATION 1 = 3

NUMBER OF FAILURES IN ITERATION 2 = 0

NUMBER OF FAILURES IN ITERATION 3 = 3

NUMBER OF FAILURES IN ITERATION 4 = 6

NUMBER OF FAILURES IN ITERATION 5 = 1

NUMBER OF FAILURES IN ITERATION 6 = 2

NUMBER OF FAILURES IN ITERATION 7 = 3

NUMBER OF FAILURES IN ITERATION 8 = 0

NUMBER OF FAILURES IN ITERATION 9 = 4

NUMBER OF FAILURES IN ITERATION 10 = 5

AVERAGE NUMBER OF FAILURES FOR ENGINE 1 IS .2
AVERAGE NUMBER OF FAILURES FOR ENGINE 2 IS .5
AVERAGE NUMBER OF FAILURES FOR ENGINE 3 IS 1
AVERAGE NUMBER OF FAILURES FOR ENGINE 4 IS .5
AVERAGE NUMBER OF FAILURES FOR ENGINE 5 IS .5
```

FIGURE 20 SHRTWEIB OUTPUT SCREEN 2

```
                      PROGRAM ETACALC




DATA INPUT ------- INPUT DATA AS INSTRUCTED

TYPE IN THE FOLLOWING DATA STATEMENT TO INPUT THE WEIBULL SLOPE
'BETA' AND THE TOTAL NUMBER OF FAILURES:
1700 DATA B,T
          WHERE 'B' IS BETA AND 'T' IS THE TOTAL NUMBER OF
          FAILURES. IF THERE ARE NO FAILURES, INPUT 1 FOR T.

THEN TYPE IN THE FOLLOWING STATEMENT TO INPUT THE DATA PAIRS:
1800 DATA N1,T1,N2,T2,...,etc.
          WHERE N1 IS THE NUMBER OF UNITS AT TIME T1, AND
                T1 IS THE OPERATING TIME ON UNITS N1.
                N2 IS THE NUMBER OF UNITS AT TIME T2, AND
                T2 IS THE OPERATING TIME ON UNITS N2, etc.

WHEN ALL DATA HAS BEEN ENTERED, TYPE 'RUN 100' AND <ENTER>.
Break in 60
Ok
```

FIGURE 21 ETACALC INPUT SCREEN

```
          CALCULATION OF THE CHARACTERISTIC LIFE ETA
        BASED ON KNOWN FAILURES AND WEIBULL SLOPE BETA




DATA PAIRS:              (NO. OF ENGS. AND TIME ON ENGS.)
     40, 19138, 48, 41578, 54, 59636, 44, 78536, 38, 96564,
     22, 111132, 48, 130206, 94, 145124, 38, 164920, 38, 183006,
     29, 201298, 39, 220112,

THE CALCULATED VALUE OF ETA IS 142914.8

THE VALUE OF BETA USED IS 3
```

FIGURE 22 ETACALC OUTPUT SAMPLE

```
                    CONFIDENCE INTERVAL CALCULATION
                                 FOR
                   BETA - ETA - TIME TO FIRST FAILURE




WHICH CONFIDENCE LEVEL (0.99, 0.95, OR 0.90) DO YOU WISH TO USE
TO ESTABLISH A CONFIDENCE INTERVAL AROUND BETA AND ETA? .9


WHAT IS THE ESTABLISHED VALUE OF BETA? 3

WHAT IS THE ESTABLISHED OF ETA? 2000

WHAT NUMBER OF FAILURES ARE THESE VALUES OF BETA AND ETA BASED
ON? 10
```

FIGURE 23 CNFINTBE INPUT SCREEN

```
                    CONFIDENCE INTERVAL CALCULATION
                                 FOR
                   BETA - ETA - TIME TO FIRST FAILURE



***************************************************************

THE CONFIDENCE INTERVALS, OR MEASUREMENT OF THE PRECISION OF THE
ESTIMATION OF BETA AND ETA ARE:

                         1.999427 <= BETA <= 4.501291
                         1667.089 <= ETA  <= 2399.392

FOR BETA AND ETA ESTIMATES OF 3 AND 2000 AND A CONFIDENCE LEVEL
OF .9

***************************************************************
```

FIGURE 24 CNFINTBE OUTPUT SCREEN

parts in a particular sample have been test or run to failure.

The next option asks if the user would like to calculate the confidence interval for the time to first failure. Choosing this option automatically loads the appropriate code without returning to the Weibull Executive Routine (WEIBER). Here you are asked for all the same type of input as before (Beta, Eta, and number of failures) as well as the estimated or calculated value of time to first failure. The input screen is shown in figure 25. As in the previous case, the range of expected values for time to first failure is given and for record purposes the estimated value. Again, this range is a measure of the precision in estimating the time to first failure and is presented at a ninety percent confidence level. In this case the ninety percent confidence level is constant and is not user selectable.

8. <u>RELIABTY & CNFINREL</u> are two codes which are grouped together for convenience as were the previous two codes. The first code (RELIABTY) calculates the reliability at any given time. The required input is given at screen prompts and consists of Beta, Eta and the time at which the reliability is desired. These are shown in figure 26. The output consists of the reliability, the probability of failure, and the time at which they were calculated. The output is shown in figure 27. As in the previous two codes, the user is queried whether it is desired to calculate the confidence interval for reliability. If the answer is yes (Y) the next code (CNFINREL) is automatically loaded so that calculations can be made and the results presented on the screen as well as on the printer for record purposes. Input data are similar: (1) Beta, (2) Eta, (3) time at which reliability is calculated, and (4) the number of failures that Beta and Eta are based on. The input is shown in figure 28. The confidence level is also selected from 0.90, 0.95, or 0.99. These codes are grouped together and run in a similar manner as the previous two codes.

9. <u>BETAHIST</u> is a code which automatically provides a hard copy of reference values of Beta for various modes of failure. It is for use where there is insufficient data to calculate Beta from actual failures, either through code number one or graphically. This code is intended to be constantly updated and to be a comprehensive data base in the future. A copy of the hard copy printout is shown as Figure 29.

10. <u>PWAWEIBL</u> is a code that has essentially the same functions as SUSWEIBL (code number one), plus the capability of determining the maximum likelihood values of Beta and Eta. The maximum likelihood values of Beta and Eta are those values which maximize the 'likelihood' of obtaining

CONFIDENCE INTERVAL CALCULATION
FOR
TIME TO FIRST FAILURE

VERSION OF 03 OCT 1986

VALUE OF BETA USED IS: 3

VALUE OF ETA USED IS: 2000

NUMBER OF FAILURES BETA AND ETA ARE BASED ON IS: 10

CONFIDENCE INTERVAL CALCULATION
FOR
TIME TO FIRST FAILURE

VERSION OF 03 OCT 1986

WHAT IS THE VALUE OF BETA TO BE USED IN THIS ANALYSIS? 3

WHAT IS THE VALUE OF ETA TO BE USED IN THIS ANALYSIS? 2000

WHAT NUMBER OF FAILURES ARE THESE VALUES OF BETA AND ETA BASED ON? 10

WHAT IS THE ESTIMATED (CALCULATED) VALUE OF TIME TO FIRST FAILURE? 1200

THE CONFIDENCE INTERVAL, OR MEASUREMENT OF PRECISION OF THE ESTIMATE OF THE TIME TO FIRST FAILURE IS:

332.9696 <= TIME TO FIRST FAILURE <= 1336.49

THE ESTIMATED VALUE OF TIME TO FIRST FAILURE IS: 1200

FIGURE 25 CNFINTBE INPUT & OUTPUT SCREENS

```
                    RELIABILITY
     CALCULATES RELIABILITY AS A FUNCTION OF TIME



INPUT THE VALUE OF BETA (WEIBULL SLOPE) TO USE? 3

INPUT THE VALUE OF ETA (CHARACTERISTIC LIFE) TO USE? 2000

INPUT THE TIME FOR WHICH YOU WANT THE RELIABILITY CALCULATED?
1200
```

FIGURE 26   RELIABTY INPUT SCREEN

```
                    RELIABILITY
     CALCULATES RELIABILITY AS A FUNCTION OF TIME




     THE RELIABILITY AT TIME 1200 IS .8057353
     THE PROBABILITY OF FAILURE AT THIS TIME IS .1942647


     THE VALUES OF BETA AND ETA USED WERE 3 AND 2000


DO YOU WISH TO CALCULATE THE RELIABILITY FOR ANOTHER TIME (ANSWER
Y OR N)?


DO YOU WISH TO CALCULATE THE CONFIDENCE INTERVAL FOR RELIABILTY
(ANSWER Y OR N)? Y
```

FIGURE 27   RELIABTY OUTPUT SCREEN

```
                    CONFIDENCE INTERVAL CALCUALTION
                                 FOR
                             RELIABILITY
                        VERSION OF 24 FEB 1987



INPUT THE VALUE OF BETA (WEIBULL SLOPE) TO USE? 3

INPUT THE VALUE OF ETA (CHARACTERISTIC LIFE) TO USE? 2000

INPUT THE TIME FOR WHICH YOU WANT THE CONFIDENCE INTERVAL
CALCULATED? 1200

INPUT THE SAMPLE SIZE ON WHICH BETA AND ETA ARE BASED? 10

WHICH CONFIDENCE LEVEL (0.99, 0.95, OR 0.90) DO YOU WISH TO USE
TO ESTABLISH A CONFIDENCE INTERVAL AROUND THE RELIABILITY? .9



          .5407021 <= RELIABILITY <= .9269299

WHERE RELIABILITY IS .8057353 FOR BETA = 3, ETA = 2000, AND
TIME = 1200
```

FIGURE 28 CNFINREL INPUT AND OUPUT SCREENS

```
***** VALUES OF BETA (WEIBULL SLOPE) FROM HISTORICAL TRENDS ****


* BEARINGS, GENERAL FAILURES.....................1.5
* CRACK, FLANGE..................................9.5
* EROSION, TURBINE VANE..........................3.0
* LCF, COMPRESSOR CASE...........................5.0
* LCF, COMPRESSOR DISK...........................3.0
* LCF, NOZZLE BEARINGS...........................1.5
* LCF, GENERAL...................................2.0--->5.0
* PERFORMANCE DETERIORATION......................4.0--->5.0
* ROTATING STRUCTURE.............................6.0--->8.0
* STATIC STRUCTURE...............................4.0--->6.0
* THERMAL LCF, COMBUSTOR.........................3.0


* INDEPENDENT OF TIME
* INGESTION (FOD) AND MISUSE
* INSUFFICIENT REDUNDENCY
* MAINTENANCE ERRORS
* MIXTURE OF PROBLEMS
* ORIGINAL DESIGN DEFFICIENCIES
* RANDOM FAILURES................................1.0


* SLOPES LESS THAN 1.0 ARE INFANT MORTALITY WHERE RELIABILITY
WILL INCREASE WITH AGE. ALSO INDICATES A QUALITY PROBLEM SUCH AS
MISASSEMBLY USUALLY HAS A VALUE AROUND 0.5.

* SLOPES GREATER THAN 1.0 ARE GENERALLY WEAROUT FOR ONE REASON OR
ANOTHER.

* A SLOPE OF 2.5 IS USUALLY GRADUAL WEAROUT.

* A SLOPE OF 3.44 APPROXIMATES A BELL SHAPED CURVE (NORMAL
DISTRIBUTION).

* A SLOPE GREATER THAN ABOUT 4.5 ARE USUALLY RAPID WEAROUT (BRICK
WALL).
```

FIGURE 29   BETAHIST OUTPUT SCREEN

the observed data. They are mathematically most likely to yield the failure data used to 'calculate' Beta and Eta. The code also allows the input of a histogram or failure and suspended data, whichever is available and more accurate or complete. The code gives the same output as the SUSWEIBL code, except that there are no instantaneous failure rate data or B10/B50 lives presented. If all of this data is desired it is recommended that both codes be run to obtain the desired answers as well as to compare the common values obtained. Be sure that the input data is the same and the same number of failures are used. Input and out put screens are shown as figures 30 through 33.

11. **BIGWEIBL** is another version of the previously described Monte Carlo analysis. This version was specifically optimized to run a maximum number of units or parts failing under a single failure mode. This code should be used only after the dominant failure mode has been determined by using code four (WEIBRISK). The purpose of this code is to determine how many failures to expect over an extended period of time, such as five to ten years, out of a fleet of up to 1100 or more engines. The input is the same as for the WEIBRISK and SHRTWEIB codes (four and five) and the output is the same as in SHRTWEIB (code five) - total failures and averages. It is very important to input data correctly and accurately since the code requires an extended time to run when the number of parts or engines approaches the maximum of over 1100. Typically on an ITT-XTRA it takes about forty-five minutes to run 1149 engines, ten years, sixty hours per month, and to make a total of ten iterations. Since the input is identical with the previous Monte Carlo codes and the output is the same as SHTWEIB2, no input or output screens are illustrated here. If the program will not run because of an out of memory error, go back an reduce the number of engines in the analysis. Also remember that the number of failure modes should not exceed one in order to maximize the number of engines that can be run.

12. **WEIBAYES** is a code that is used when there is insufficient failure data to calculate critical life for a failure mode that is known to exist. Typically the failure mode will give some idea as to the Weibull slope Beta, either from past history or from code nine - BETAHIST. It is for this reason that it is important to record all values of Beta and their corresponding failure modes. The WEIBAYES input screen, not shown, asks if the value of the characteristic life Eta is known. If Eta is not known the user will be directed to go to the ETACALC code (code six) to calculate a best estimate of Eta. Strictly speaking code number six is the WEIBAYES calculation of the value of 'ETA'. The WEIBAYES code uses that value of 'ETA' to calculate a user designated value of critical life. If Eta is known, or upon returning from code six, input data will

```
                WEIBULL PARAMETER CALCULATION
             PRATT & WHITNEY AIRCRAFT -GPD - UTC
                AS IMPROVED BY CODE 6052
              NAVAL AIR DEVELOPMENT CENTER
                WARMINSTER, PA 18974






ARE YOU INPUTTING A HISTOGRAM OF SUSPENSIONS?


ANSWER Y OR N?
```

FIGURE 30 PWAWEIBL INTRODUCTORY SCREEN

```
INPUT THE FAILURE DATA AND SUSPENSIONS WITH DECIMAL...USE -99999
TO INDICATE THE END OF THE DATA (NEGATIVES INDICATES SUSPENSIONS,
UNLESS A HISTOGRAM WAS INPUT)


? 100
? 250
? 310
? 500
? 675
? -99999
```

FIGURE 31 PWAWEIBL INPUT SCREEN

POINT	DATA	ORDER	MEDIAN RANK
1	100	1	.1296296
2	250	2	.3148148
3	310	3	.5
4	500	4	.6851852
5	675	5	.8703703

```
BETA = 1.423798            ETA = 429.7823


DO YOU WISH TO DA A MAXIMUM LIKELIHOOD ESTIMATION?
ANSWER Y OR N?
Break in 1100
Ok
```

FIGURE 32 PWAWEIBL OUTPUT SCREEN 1

```
                PLEASE BE PATIENT........IT'S ITERATING


MAXIMUM LIKELIHOOD ESTIMATES FOLLOW


BETA = 1.922156            ETA = 414.6144

DO YOU HAVE ANOTHER ANALYSIS TO DO?

ANSWER Y OR N? N
```

FIGURE 33 PWAWEIBL OUTPUT SCREEN 2

be requested next in the form of data statements as shown in figure 34. The first input requested is the B.1 life (or other value (such as B.001, B10, etc.) or percent of the population allowed to fail. If the part being investigated is a critical part, such as a disk, then the input should be a very low B-life. Any number can be input up to 0.999999, which is equivalent to 99.9999%. If the desired life was the B10 life then the input would be:

```
4000 DATA 0.10
```

The next input is the assumed value of Beta and the calculated Eta. This input would appear as:

```
4040 DATA 3,1000
```

if Beta were three and Eta were 1000.

The code now calculates the percent allowed to fail and the equivalent number of hours to arrive at that percent failures. The output screen is shown in Figure 35 and contains a short explanation of the answer. It also gives the user an opportunity to make another calculation if the answer is unsuitable. This code is especially useful for critical life parts where even one failure can be considered catastrophic. Requirements can be determined for parts life improvement to achieve a desired specific life in terms of an allowed failure percentages.

13. <u>ZOFAILSB</u> is a code that provides the definition of a test plan that will demonstrate that a redesigned part has either eliminated or substantially improved a known failure mode. The resulting plan, when passed, represents substantiation that an engineering change or fix has solved the problem presented by the failure mode. This particular test plan generation is for those cases where there will be some fixed number of test units, each tested for a certain number of hours or cycles, without any failures. If there is a failure prior to each test unit completing the required number of hours, the test is failed. Zero failures means the statistical requirement has been met for substantiation of the fix.

The inputs for this code are: (1) the Weibull slope Beta, (2) the characteristic life Eta, and (3) an assumed number of test hours that each test article must successfully complete. The input screen is shown as figure 36. The code first calculates the ratio of the test hours to the characteristic life and then presents a table on the screen from which the number of required test articles can be determined. See figures 37 and 38. The upper limit of test articles has been chosen as fifty and the lower limit is a statistical limit of three. Since the table can still indicate the requirement to test a very large and

```
                    WEIBAYES ANALYSIS
             WHEN WEIBULL PLOTS ARE IMPOSSIBLE
               DUE TO A LACK OF FAILURE DATA




DATA INPUT ---------- ENTER THE FOLLOWING:

4000 DATA BX
               WHERE BX = THE PERCENT OF THE POPULATION ALLOWED
               TO FAIL, i.e., 0.001 FOR B.1 LIFE
               DO NOT USE 1.0 OR ANY PERCENT > 0.999999

4040 DATA B,H
               WHERE B = THE ASSUMED VALUE OF THE WEIBULL SLOPE
               'BETA' AND H = THE CALCULATED VALUE OF THE
               CHARACTERISTIC LIFE 'ETA'
WHEN ALL DATA IS ENTERED, INPUT <RUN 1849> TO CONTINUE.
     Break in 1846
     Ok
```

FIGURE 34 WEIBAYES INPUT SCREEN

```
               LIFE CALCULATIONS FOR WEIBAYES


PERCENT OF POPULATION ALLOWED TO FAIL = 99.9999 (CALCULATED
VALUE).

THE CALCULATED LIFE USING THE INPUT VALUE OF BX IS EQUAL TO
2398.745

IF THIS VALUE IS SMALLER THAN ACCETABLE THEN THE CALCULATED VALUE
OF ETA (CHARACTERISTIC LIFE) IS TOO SMALL. THIS MAY BE DUE TO A
LACK OF SUFFIECIENT OPERATING TIME USED IN THE CALCULATION OF
ETA. INSUFFICIENT DATA INDICATES A NEED TO EXERCISE CONSERVATISM
UNTIL ENOUGH OPERATIONAL EXPERIENCE IS OBTAINED WITHOUT A FAILURE
(OR FEW FAILURES) SUCH THAT A HIGHER VALUE OF ETA IS CALCULATED.

BETA USED WAS 3          ETA USED WAS 1000.
```

FIGURE 35 WEIBAYES OUTPUT SCREEN

```
                ZERO FAILURE TEST PLAN GENERATION
         NUMBER OF TEST UNITS AND TEST TIME FOR EACH
                      VERSION 17 MAY 1987



THIS CODE CALCULATES THE STATISTICAL REQUIREMENT FOR
SUBSTANTIATION TESTING THAT DEMONSTRATES A REDESIGNED PART /
SYSTEM HAS ELIMINATED OR SIGNIFICANTLY IMPROVED  A KNOWN  FAILURE
MODE - BETA AND ETA ARE ASSUMED TO BE KNOWN.

THE RESULTING TEST PLAN GIVES:
               1. THE REQUIRED NUMBER OF TEST UNITS
               2. TEST TIME TO BE ACCUMULATED ON EACH UNIT

FIFTY (50) IS THE UPPER LIMIT OF TEST UNITS AND TEST TIME
EXPRESSED AS A FRACTION OF THE CHARACTERISTIC LIFE, ETA.
                    RATIO = (TEST TIME)/(CHARACTERISTIC LIFE)
                                       OR
                    TEST TIME = RATIO * CHARACTERISTIC LIFE

INPUT THE WEIBULL SLOPE BETA (BETA <=5.0 ONLY) FOR THE FAILURE
MODE?
```

FIGURE 36   ZOFAILSB INPUT SCREEN 1

```
USUALLY A TEST PROGRAM IS DRIVEN BY A PRACTICAL LEVEL OF TEST
TIME WHICH IS VERY EXPENSIVE.

MAKE AN ESTIMATE OF A REASONABLE TEST TIME, REORGANIZING THAT AT
LEAST THREE (3) UNITS OR MORE MUST EACH BE TESTED FOR THAT TIME

INPUT TEST HOURS? 1500

RATIO = .75     BETA = 2.5

NOW CHOOSE THE NEAREST VALUE OF THE WEIBULL SLOPE BETA AND RATIO
OF TEST TIME TO THE CHARACTERISTIC LIFE THAT IS IN THE FOLLOWING
TABLE. MAKE A NOTE OF THE SAMPLE SIZE FROM THE TABLE.


PRESS ENTER TO CONTINUE.
```

FIGURE 37   ZOFAILSB INPUT SCREEN 2

RATIO	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0.01	24	**	**	**	**	**	**	**	**	**
0.02	17	**	**	**	**	**	**	**	**	**
0.03	14	**	**	**	**	**	**	**	**	**
0.04	12	**	**	**	**	**	**	**	**	**
0.05	11	47	**	**	**	**	**	**	**	**
0.06	10	39	**	**	**	**	**	**	**	**
0.07	9	33	**	**	**	**	**	**	**	**
0.08	9	29	**	**	**	**	**	**	**	**
0.09	8	26	**	**	**	**	**	**	**	**
0.10	8	24	**	**	**	**	**	**	**	**
0.20	6	12	26	**	**	**	**	**	**	**
0.30	5	8	15	26	47	**	**	**	**	**
0.40	4	6	10	15	23	36	**	**	**	**
0.50	4	5	7	10	14	19	27	37	**	**
0.60	3	4	5	7	9	11	14	18	23	30
0.70	3	4	4	5	6	7	9	10	12	14
0.80	3	3	4	4	5	5	6	6	7	8
0.90	3	3	3	3	3	4	4	4	4	4
1.00	3	3	3	3	3	3	3	3	3	3

** INDICATES SAMPLE SIZE EXCEEDS 50-INPUT 99 FOR SAMPLE SIZE

BETA = 2.5 RATIO = .75

PRINT SCREEN FOR HARD COPY OF THE TABLE. INPUT THE SAMPLE SIZE FROM THE TABLE? 6

FIGURE 38 ZOFAILSB TABLE

SAMPLE SIZE = 6

IF A REASONABLE RATIO TEST TIME TO ETA HAS RESULTED IN AN UNREASONABLE SAMPLE (OR A SAMPLE SIZE OF OVER FIFTY, INDICATED BY **) YOU SHOULD NOW MAKE ANOTHER ESTIMATE OF TEST HOURS OR OPT FOR ANOTHER METHOD OF TEST PLAN DETERMINATION.

PLEASE CHOOSE FROM THE FOLLOWING OPTIONS:

1. DISPLAY THE TEST PLAN FOR CURRENT SAMPLE SIZE OF 6
2. MAKE ANOTHER ESTIMATE OF TEST HOURS.
3. USE ALTERNATE TEST PLAN METHOD.

INPUT OPTION NUMBER FROM THE ABOVE LIST?

FIGURE 39 ZOFAILSB OUTPUT SCREEN 1

```
THE TEST PLAN CONSISTS OF THE FOLLOWING:

                    SAMPLE SIZE IS 6

                    TEST HOURS ARE 1500

IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE
FAILURE MODE WHERE
                    BETA = 2.5   AND    ETA = 2000

HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED.
THE TEST TIME IS 75 PERCENT OF THE CHARACTERISTIC LIFE OF 2000
HOURS.
```

FIGURE 40 ZOFAILSB OUTPUT SCREEN 2

```
THE ALTERNATE TEST PLAN METHOD REQUIRES THE INPUT OF A REASONABLE
NUMBER OF UNITS FOR TEST (SAMPLE SIZE) AND THE SELECTION OF A
TEST HOUR RATIO FROM THE FOLLOWING TABLE. MAKE AN ESTIMATE OF A
REASONABLE SAMPLE SIZE? 4

NOW CHOOSE THE NEAREST VALUE OF THE WEIBULL SLOPE BETA AND THE
SAMPLE SIZE YOU JUST ESTIMATED AND THEN NOTE THE CORRESPONDING
TEST HOUR RATIO.


PRESS ENTER TO CONTINUE?
```

FIGURE 41 ZOFAILSB ALTERNATE PLAN INPUT SCREEN inappropriate number of test articles, the code next gives the opportunity to revise the test hours in order to adjust the number of required test articles (figures 39 and 40). This adjustment is usually upward since that results in fewer test articles. After one or more adjustments to the test hours it may be apparent that the solution is still not converging to an acceptable number of test articles. In this case there is the choice available to use an alternate test plan method. See option 3 on figure 39.

Using the alternate test plan method requires the initial selection of a reasonable number of test articles as well as Beta and Eta (see figure 41). The code then presents another table (figure 42) which allows a resulting number of test hours to be determined. Again, the opportunity is presented to make another choice if the test plan still is not optimum. This procedure can be repeated as many times as required in order to arrive at the optimum zero-failure test plan. It should be noted that an optimum zero-failure test plan almost always results in fewer total test hours than plans generated to allow for one or more failures. Optimum in this case would be for a minimum of total test time.

14. NZFTESTP is a code that provides substantiation that a fix has either eliminated a failure mode or significantly improved it. In this case one or more failures are allowed, hence it is a non-zero-failure test plan. The introductory screen is shown in figure 43. Inputs are shown in figure 44. The first input is the probability of passing the test, demonstrating a significantly improved failure characteristic, if no fix is introduced. This obviously is a small probability such as ten percent, or 0.1. Next is input the probability of passing the test if a good fix is introduced. This should be a much higher probability such as ninety percent, or 0.9. The next inputs are the characteristic life Eta before the fix and the desired characteristic life with the fix. The increase in Eta should indicate a significant decrease in the probability of an early failure. Next, a reasonable number of test hours is input which represents the target test time that each test article is to be tested to. The last input is the Weibull slope Beta for the failure mode in question.

The code now runs in an iterative mode which halts at certain points that show agreement between the assumed probabilities of passing the tests and the calculated values. The screen displays these interim results and as the calculation stops, the user is asked to press the F5 (Function 5) key to continue the iteration. Figures 45 and 46 show samples of the iterative screens. When the last iteration is complete the code automatically shows a table of results (figure 47). The user is asked to select values from this table, (N0, N1, and R0) and input them at the prompts. The final calculation is then made to result in the final test plan. The results are presented on the screen (See figure 48) in terms of a sample size, each of which must be tested for some reasonable amount of time that was input earlier. The allowed number of failures, which must not be exceeded, is also given. Also presented is the total number of test hours that would be run assuming there were no test failures. This represents the maximum test

BETA

SAMPLE SIZE	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
3	.589	.767	.838	.876	.900	.916	.927	.936	.943	.948
4	.331	.576	.692	.759	.802	.832	.854	.871	.884	.895
5	.212	.460	.596	.679	.772	.722	.801	.824	.842	.856
6	.147	.384	.528	.619	.682	.727	.761	.787	.808	.826
7	.108	.329	.477	.574	.641	.690	.728	.757	.781	.801
8	.083	.288	.436	.536	.608	.660	.701	.732	.758	.780
9	.065	.256	.403	.506	.580	.635	.677	.711	.739	.761
10	.053	.230	.376	.480	.556	.613	.657	.693	.722	.745
12	.037	.192	.333	.438	.517	.577	.624	.662	.693	.719
14	.027	.164	.300	.406	.486	.548	.597	.637	.670	.697
16	.021	.144	.275	.379	.461	.524	.575	.616	.650	.679
18	.016	.128	.254	.358	.439	.504	.556	.598	.633	.663
20	.013	.115	.237	.339	.421	.486	.539	.582	.619	.649
25	.008	.092	.204	.303	.385	.452	.506	.551	.589	.621
30	.006	.077	.181	.277	.358	.425	.480	.526	.565	.598
40	.003	.058	.149	.240	.319	.386	.442	.490	.530	.565
50	.002	.046	.128	.215	.292	.358	.415	.463	.505	.540

BETA = 2.5 SAMPLE = 4

PRINT SCREEN FOR HARD COPY OF TABLE. INPUT TEST HOUR RATIO FROM TABLE?

FIGURE 42 ZOFAILSB ALTERNATE PLAN TABLE

PROGRAM TO GENERATE A NON-ZERO FAILURE TEST PLAN
SAMPLE SIZE REQUIRED FOR GIVEN TEST TIME

THESE TEST PLANS WILL HAVE THE FOLLOWING STRUCTURE:

A. PUT N ITEMS ON TEST FOR T HOURS (CYCLES) EACH.
B. WHEN AN ITEM ON TEST FAILS, IT NOT REPAIRED.
C. IF R0 OR FEWER FAILURES OCCUR, THE TEST IS PASSED.

FIGURE 43 NZFTESTP INTRODUCTORY SCREEN

```
INPUT VALUE OF PROBABILITY OF PASSING TEST WITH ETA OF FAIL MODE.
THIS IS ONE MINUS THE PERCENT CONFIDENCE OF THE VALUE OF ETA -
USUALLY 0.1

A0=? .1

INPUT VALUE OF PROBABILITY OF PASSING TEST WITH ETA DESIRED
THIS IS THE PERCENT CONFIDENCE OF ETA DESIRED - USUALLY 0.9

A1=? .9

INPUT VALUE OF ETA FOR FAIL MODE? 2000

INPUT VALUE OF ETA DESIRED? 4000

INPUT NUMBER OF TEST HOURS EACH TEST ARTICLE? 1000

INPUT VALUE OF BETA FOR FAIL MODE? 2.5
```

FIGURE 44 NZFTESTP INPUT SCREEN

```
A0=.1          G0=.837967     N0=1
A0=.1          G0=.7021886    N0=2
A0=.1          G0=.5884108    N0=3
A0=.1          G0=.4930688    N0=4
A0=.1          G0=.4131753    N0=5
A0=.1          G0=.3462272    N0=6
A0=.1          G0=.290127     N0=7
A0=.1          G0=.2431168    N0=8
A0=.1          G0=.2037238    N0=9
A0=.1          G0=.1707138    N0=10
A0=.1          G0=.1430526    N0=11
A0=.1          G0=.1198733    N0=12
A0=.1          G0=.1004499    N0=13

          PRESS F5 KEY TO CONTINUE
Break in 1662
Ok
```

FIGURE 45 NZFTESTP ITERATION SCREEN 1

```
A1= .9         G1= .9692332   N1= 1
A1= .9         G1= .939413    N1= 2
A1= .9         G1= .9105103   N1= 3

22.82147
5.266494
               PRESS F5 TO CONTINUE
Break in 1912
Ok
```

FIGURE 46 NZFTESTP ITERATION SCREEN 2

A0	G0	N0	A1	G1	N1	M	R0
.1	.1004499	13	.9	.9105103	3	22.82147	0
.1	.1075184	22	.9	.9051063	17	6.815463	1
.1	.1016429	31	.9	.9079262	35	4.664609	2
0	0	0	0	0	0	0	3
0	0	0	0	0	0	0	4
0	0	0	0	0	0	0	5

NOW SELECT THE LAST TWO VALUES OF M AND COMPARE THEM WITH :

N = 5.266494

THE FINAL VALUE OF N0 AND N1 ARE THE VALUES WHICH ARE IN THE ROW VARIABLES THAT CONTAINS THE VALUE OF M CLOSEST TO THAT OF N - EITHER + OR -.:?
INPUT THESE VALUES OF N0 AND N1 AT THE PROMPTS

INPUT N0:
? 31
INPUT N1:
? 35
INPUT R0:
?2

FIGURE 47 NZFTESTP OUTPUT SCREEN 1

THE SAMPLE SIZE, EACH OF WHICH MUST BE TESTED FOR 1000 HOURS, IS:

SAMPLE SIZE = 33

IF 2 OR LESS FAILURES OCCUR THE TEST IS PASSED.

MAXIMUM TOTAL TEST HOURS IF ALL TEST UNITS RUN W/O FAILURE = 33000 HOURS

FIGURE 48 NZFTESTP OUTPUT SCREEN 2

hours that would be run for a 100% successful test. This number can be used as an indication of whether the test is too long. Also, the number of test articles may be too large and require that a new test plan be formulated with a higher number of test hours per test article. Whatever the result, the user is given the opportunity to do another analysis or quit and return to the menu.

SAMPLE SOLUTIONS

This section contains sample solutions for each of the codes addressed in this report, including WEIBER, which shows the menu and the Help screens. The sample solutions are meant to be illustrative only and are not meant to represent any specific engine or actual engine or parts problem. It is hoped that between the sample solutions, the previous explanations, and the code listing of Appendix A, readers with a desire to utilize the codes will be successful without spending a great deal of time in the learning process. As the codes mature with further use and modification, they will become more useful and be applicable to a broader range of gas turbine engine problems. A more comprehensive user's manual may also be written in the near future if it is required.

* * * HELP FOR WEIBULL ANALYSIS ROUTINE * * *

THIS IS A SYSTEMATIC ROUTINE FOR MAKING FAILURE ANALYSES BASED ON THE WEIBULL DISTRIBUTION METHODOLOGY. THE SERIES OF CODES THAT MAKE UP THE ROUTINE ARE WRITTEN FOR GAS TURBINE ENGINE PART FAILURES BUT CAN BE APPLIED TO ANY TYPE EQUIPMENT THAT CORRELATES IN A WEIBULL DISTRIBUTION.

THE FOLLOWING IS A LIST OF THE AVAILABLE CODES AND THEIR FUNCTIONS. YOU MAY USE ANY CODE AS A STAND-ALONE ANALYTICAL TOOL.

PRESS ANY KEY TO CONTINUE.?

1. WEIBULL PARAMETER CALCULATION (SUSWEIBL) - THIS CODE IS USED TO CALCULATE THE WEIBULL SLOPE 'BETA' AND THE CHARACTERISTIC LIFE 'ETA' USING A SAMPLE COMPOSED OF BOTH FAILURES AND SUSPENDED UNITS. SUSPENDED UNITS ARE THOSE THAT ARE NON-FAILED OR NOT FAILED BY THE MODE UNDER CONSIDERATION. DATA REQUIRED ARE: (1) NUMBER OF UNITS IN THE SAMPLE, (2) NUMBER OF FAILED UNITS IN THE SAMPLE, AND (3) NUMBER AND AGE OF EACH UNIT OR GROUP OF UNITS WITH THE SAME AGE. THE OUTPUT FROM THIS CODE IS : (1) BETA, (2) ETA, (3) B-10 LIFE, (4) B-50 LIFE, (5) LEAST SQUARES CORRELATION COEFFICIENT, AND (6) THE INSTANTANEOUS FAILURE RATE VERSUS THE AGE OF THE UNITS. IF BETA IS KNOWN, OR IF YOU HAVE A GOOD ESTIMATE OF BETA, YOU MAY USE OPTION 6, 'CHARACTERISTIC LIFE CALCULATION.'

PRESS THE ENTER KEY TO CONTINUE.?

2. PRESENT RISK ANALYSIS (PRESRISK) - THIS CODE IS USED TO CALCULATE THE EXPECTED NUMBER OF FAILURES TO HAVE OCCURRED TO DATE OVER THE LIFE OF THE UNITS OF THE SAMPLE. THE CODE IS EXCELLENT FOR VERIFYING THE FAILURES AS WELL AS 'ETA' BY COMPARING ANSWERS WITH KNOWN FAILURES IN THE POPULATION. DATA REQUIRED ARE; (1) BETA, (2) ETA, (3) NUMBER AND AGE OF EACH UNIT OR GROUP OF UNITS WITH THE SAME AGE. THE OUTPUT FROM THE CODE IS: (1) THE PERCENT IN EACH GROUP EXPECTED TO FAIL, (2) THE NUMBER IN EACH GROUP EXPECTED TO FAIL, AND (3) THE TOTAL NUMBER OF EXPECTED FAILURES FOR THE POPULATION.

PRESS THE ENTER KEY TO CONTINUE.?

3. FUTURE RISK ANALYSIS (FUTRISKS) - THIS CODE IS USED TO CALCULATE THE EXPECTED NUMBER OF FAILURES OVER A SPECIFIED FUTURE TIME PERIOD FOR A POPULATION THAT ACCUMULATES MORE OPERATING TIME OVER THAT TIME PERIOD. IT IS ASSUMED THAT THERE ARE NO REPAIRS SO FAILURES ARE FOR THE ORIGINAL POPULATION ONLY. FOR A MORE COMPLEX ANALYSIS WHERE PARTS ARE REPAIRED AND RETURNED TO SERVICE, SEE OPTION 4, THE MONTE CARLO RISK ANALYSIS. DATA REQUIRED ARE: (1) BETA, (2) ETA, (3) MONTHS INTO THE FUTURE THAT THE ANALYSIS WILL COVER, (4) AVERAGE MONTHLY OPERATING HOURS PER UNIT OVER THE TIME PERIOD, AND (5) NUMBER AND AGE OF EACH GROUP OF UNITS WITH THE SAME AGE. THE OUTPUT FROM THIS CODE IS: (1) THE PERCENT IN EACH GROUP EXPECTED TO FAIL, (2) THE NUMBER IN EACH GROUP EXPECTED TO FAIL, (3) CUMULATIVE FAILURES, AND (4) THE TOTAL NUMBER OF EXPECTED FAILURES IN THE POPULATION.

PRESS THE ENTER KEY TO CONTINUE.?

4. WEIBULL FAILURE ANALYSIS - MONTE CARLO (WEIBRISK) - THIS CODE IS A COMPREHENSIVE ANALYTICAL TOOL THAT CAN BE USED TO FORECAST NUMBERS OF FAILURES AS WELL AS THE FAILURE TIMES IN TERMS OF OPERATING HOURS OR CYCLES. IT IS A STATISTICAL CODE THAT MAKES THOUSANDS OF CALCULATIONS TO ALLOW STATISTICAL AVERAGES TO BE CALCULATED. IT IS EXTREMELY ACCURATE WHEN REQUIRED INPUT DATA IS EXTREMELY ACCURATE. IT IS CAPABLE OF PROVIDING SENSITIVITIES SO THAT LESS ACCURATE DATA CAN BE USED TO ARRIVE AT REASONABLE SOLUTIONS AND ALLOW FOR IMPACT ANALYSIS. DATA REQUIRED ARE: (1) BETA, (2) ETA, (3) NUMBER AND AGE OF EACH GROUP OF UNITS WITH THE SAME INITIAL TIME, (4) TOTAL NUMBER OF ENGINES IN THE SAMPLE, (5) NUMBER OF MONTHS IN THE ANALYSIS, (6) AVERAGE OPERATING HOURS PER MONTH PER PART OVER THE TIME OF THE ANALYSIS, (7) THE INSPECTION INTERVAL AT WHICH, IF REACHED BEFORE A FAILURE OCCURS, ALL PARTS CONSIDERED ARE MADE GOOD-AS-NEW OR ZERO-TIMED, (8) NUMBER OF FAILURE MODES IN THE ANALYSIS, AND (9) THE ENGINE NAME. NOTE THAT BETA AND ETA MUST BE FURNISHED FOR EACH FAILURE MODE. ALSO NOTE THAT LARGE NUMBERS OF ENGINES AND MULTIPLE FAILURE MODES GREATLY INCREASE THE RUN TIME.

5. WEIBULL FAILURE ANALYSIS - SHORT PRINT-OUT (SHRTWEIB) - THIS CODE IS ALMOST IDENTICAL TO THE PREVIOUS CODE EXCEPT FOR THE AMOUNT OF OUTPUT. IN ORDER TO SPEED UP THE ANALYSIS, ONLY NUMBERS OF FAILURES ARE OUTPUT AND FAILURE TIMES AND MODES OF FAILURE ARE ELIMINATED. THIS CODE IS VERY USEFUL AFTER IT HAS BEEN DETERMINED WHICH FAILURE MODES DOMINATE AND SHEER NUMBERS ARE OF PRIME INTEREST. MANY MORE ENGINES MAY BE ANALYSED IN THE SAME AMOUNT OF TIME AND THE VOLUME OF PAPER GENERATED IS VERY SIGNIFICANTLY LESS.

PRESS THE ENTER KEY TO CONTINUE.?

4. WEIBULL FAILURE ANALYSIS - MONTE CARLO (WEIBRISK) - THIS CODE IS A COMPREHENSIVE ANALYTICAL TOOL THAT CAN BE USED TO FORECAST NUMBERS OF FAILURES AS WELL AS THE FAILURE TIMES IN TERMS OF OPERATING HOURS OR CYCLES. IT IS A STATISTICAL CODE THAT MAKES THOUSANDS OF CALCULATIONS TO ALLOW STATISTICAL AVERAGES TO BE CALCULATED. IT IS EXTREMELY ACCURATE WHEN REQUIRED INPUT DATA IS EXTREMELY ACCURATE. IT IS CAPABLE OF PROVIDING SENSITIVITIES SO THAT LESS ACCURATE DATA CAN BE USED TO ARRIVE AT REASONABLE SOLUTIONS AND ALLOW FOR IMPACT ANALYSIS. DATA REQUIRED ARE: (1) BETA, (2) ETA, (3) NUMBER AND AGE OF EACH GROUP OF UNITS WITH THE SAME INITIAL TIME, (4) TOTAL NUMBER OF ENGINES IN THE SAMPLE, (5) NUMBER OF MONTHS IN THE ANALYSIS, (6) AVERAGE OPERATING HOURS PER MONTH PER PART OVER THE TIME OF THE ANALYSIS, (7) THE INSPECTION INTERVAL AT WHICH, IF REACHED BEFORE A FAILURE OCCURS, ALL PARTS CONSIDERED ARE MADE GOOD-AS-NEW OR ZERO-TIMED, (8) NUMBER OF FAILURE MODES IN THE ANALYSIS, AND (9) THE ENGINE NAME. NOTE THAT BETA AND ETA MUST BE FURNISHED FOR EACH FAILURE MODE. ALSO NOTE THAT LARGE NUMBERS OF ENGINES AND MULTIPLE FAILURE MODES GREATLY INCREASE THE RUNNING TIME. THE OUTPUT FROM THIS CODE IS: (1) FAILURE TIMES (2) NEW FAILURE TIMES, (3) NUMBER OF FAILURES PER ENGINE, (4) IDENTIFICATION OF FAILURE MODE, (5) AVERAGE NUMBER OF FAILURES PER ENGINE OVER THE NUMBER OF ITERATIONS, (6) CUMULATIVE FAILURES PER ENGINE, AND (7) AVERAGE FAILURES FOR ALL ENGINES FOR ALL ITERATIONS.

PRESS ENTER KEY TO CONTINUE.?

5. WEIBULL FAILURE ANALYSIS - SHORT PRINT-OUT (SHRTWEIB) - THIS CODE IS ALMOST IDENTICAL TO THE PREVIOUS CODE EXCEPT FOR THE AMOUNT OF OUTPUT. IN ORDER TO SPEED UP THE ANALYSIS, ONLY NUMBERS OF FAILURES ARE OUTPUT AND FAILURE TIMES AND MODES OF FAILURE ARE ELIMINATED. THIS CODE IS VERY USEFUL AFTER IT HAS BEEN DETERMINED WHICH FAILURE MODES DOMINATE AND SHEER NUMBERS ARE OF PRIME INTEREST. MANY MORE ENGINES MAY BE ANALYSED IN THE SAME AMOUNT OF TIME AND THE VOLUME OF PAPER GENERATED IS VERY SIGNIFICANTLY LESS.

PRESS THE ENTER KEY TO CONTINUE.?

6. CHARACTERISTIC LIFE CALCULATION (ETACALC) - THIS CODE IS USEFUL WHEN BETA IS KNOWN FOR THE FAILURE MODE AND GOOD FAILURE DATA IS AVAILABLE TO CALCULATE ONLY THE CHARACTERISTIC LIFE. DATA REQUIRED ARE: (1) BETA, (2) TOTAL NUMBER OF FAILURES THAT DATA IS AVAILABLE FOR, AND (3) DATA PAIRS OF NUMBERS OF FAILURES AND OPERATING TIME AT FAILURE. THE OUTPUT FROM THIS CODE IS THE CALCULATED VALUE OF THE CHARACTERISTIC LIFE.

PRESS THE ENTER KEY TO CONTINUE.?

7. CONFIDENCE INTERVAL CALCULATION (CNFINTBE) - THIS CODE CALCULATES UPPER AND LOWER CONFIDENCE BOUNDS FOR BOTH BETA AND TIME TO FIRST FAILURE. CALCULATIONS CAN BE MADE FOR CONFIDENCE LEVELS OF 0.90, 0.95, OR 0.99. THESE UPPER & LOWER LIMITS ARE INDICATIONS OF THE ACCURACY ONE CAN EXPECT FROM THE MANY CALCULATIONS THAT CAN BE MADE FROM THESE CODES.

PRESS THE ENTER KEY TO CONTINUE.?

8. RELIABILITY AND CONFIDENCE INTERVALS FOR RELIABILITY (RELIABTY) - THIS CODE CALCULATES THE RELIABILITY OF A COMPONENT AT ANY TIME BASED ON THE VALUES OF BETA AND ETA. YOU MAY THEN CALCULATE THE CONFIDENCE INTERVAL FOR THIS RELIABILITY AT A CONFIDENCE LEVEL OF 0.90, 0.95, OR 0.99. ALSO PRESENTED IS THE CORRESPONDING PROBABILITY OF FAILURE.

PRESS THE ENTER KEY TO CONTINUE.?

9. HISTORICAL BETA VALUES (BETAHIST) - THIS CODE PRINTS OUT A LIST OF PROBABLE VALUES OR RANGES OF BETA FOR SOME COMMON MODES OF FAILURE IN GAS TURBINE COMPONENTS. WHILE THESE HISTORICAL VALUES SHOULD NOT BE TAKEN AS ABSOLUTE, THEY REPRESENT REASONABLE STARTING VALUES, ESPECIALLY FOR PERFORMING SENSITIVITY ANALYSES.

PRESS THE ENTER KEY TO CONTINUE.?

10. WEIBULL PARAMETER CALCULATION (PWA CO) - THIS CODE IS SIMILAR TO CODE NUMBER 1 EXCEPT THAT IT CAN PROVIDE THE VALUES OF BETA AND ETA WHICH MAXIMIZE THE 'LIKELIHOOD' OF OBTAINING THE OBSERVED DATA. THERE ARE CASES WHERE THESE VALUES MAY BE DIFFERENT THAN THOSE OBTAINED IN CODE 1 BY A REASONABLE AMOUNT. IF THERE IS A QUESTION, BOTH CODES SHOULD BE RUN AND SENSITIVITIES ESTABLISHED.

PRESS THE ENTER KEY TO CONTINUE.?

11. WEIBULL FAILURE ANALYSIS FOR OVER 1100 ENGINES/PARTS - THIS CODE IS SIMILAR TO THE PREVIOUS TWO MONTE CARLO CODES EXCEPT THAT IT IS OPTIMIZED TO ANALYZE A MAXIMUM OF ENGINES/PARTS. THIS CODE SHOULD BE USED AFTER THE DOMINANT FAILURE MODE HAS BEEN DETERMINED AND NO MORE THAN ONE FAILURE MODE SHOULD BE ANALYZED AT A TIME. THE INPUT IS THE SAME AS IN CODES (4) AND (5) BUT THE OUTPUT IS LIMITED TO THAT OF CODE (5). ONLY THE TOTAL FAILURES ARE GIVEN PER ITERATION ALONG WITH THE AVERAGES.

PRESS THE ENTER KEY TO CONTINUE.?

12. WEIBAYES, WHEN WEIBULL PLOTS ARE NOT POSSIBLE - WHEN THERE IS INSUFFICIENT FAILURE DATA TO CALCULATE THE WEIBULL SLOPE BETA AND THE CHARACTERISTIC LIFE ETA WE MAY MAKE ASSUMPTIONS TO ARRIVE AT THE BEST ESTIMATES AND MAKE CALCULATIONS TO DETERMINE THE DESIRED LIFE, i.e., B.1, B1, B10, OR B50 LIFE. FIRST, IT IS NECESSARY TO MAKE THE BEST GUESS REGARDING THE FAILURE MODE SUCH AS LCF, HCF, OR OTHERS. THEN USE CODE (6), CHARACTERISTIC LIFE CALCULATION, TO DETERMINE A BEST ESTIMATE OF ETA. THESE FORM THE INPUT FOR THIS CODE WHICH THEN CALCULATES THE APPROPRIATE LIFE OF THE PART IN QUESTION.

PRESS THE ENTER KEY TO CONTINUE.?

13. ZERO-FAILURE TEST PLAN FOR SUBSTATIATION TESTING - THIS CODE CALCULATES THE NUMBER OF ENGINES/PARTS THAT MUST BE TESTED WITHOUT FAILURE IN ORDER TO DEMONSTRATE THAT A GIVEN FAILURE MODE HAS BEEN EITHER ELIMINATED OR SUBSTANTIALLY IMPROVED. INPUTS REQUIRED ARE (1) WEIBULL SLOPE BETA, (2) CHARACTERISTIC LIFE ETA, AND (3) AN ESTIMATE OF A REASONABLE AMOUNT OF TEST TIME, RECOGNIZING THAT AT LEAST THREE PARTS OR MORE MUST EACH BE TESTED FOR THAT AMOUNT OF TIME. THE CODE ALLOWS A SECOND AND THIRD TEST TIME ESTIMATE (OR MORE) AND ALSO PROVIDES FOR AN ALTERNATE METHOD OF TEST PLAN FORMULATION. THEN TEST PLAN IS OUTPUT IN TERMS OF A SAMPLE SIZE, EACH OF WHICH MUST BE TESTED FOR A GIVEN NUMBER OF HOURS WITHOUT FAILURE IN ORDER TO DEMONSTRATE A SIGNIFICANT IMPROVEMENT IN LIFE.

PRESS THE ENTER KEY TO CONTINUE.?

```
                    WEIBULL RISK ANALYSIS ROUTINE

                     WRITTEN BY JAMES L. BYERS
                   NAVAL AIR DEVELOPMENT CENTER
                            CODE 6052
                     WARMINSTER, PA 18974

                       VERSION 2 MAY 1986

            IF YOU HAVE PROBLEMS OR COMMENTS CONTACT
          JAMES L. BYERS AT THE ABOVE ADDRESS


                             OPTIONS

     ! ! ! FOR MENU --------------------------------TYPE 100 <ENTER>
     ! ! ! FOR HELP ------------------------------- TYPE 800 <ENTER>
     ! ! ! TO QUIT -------------------------------- TYPE 900 <ENTER>



YOUR CHOICE? 100


                              MENU
                     WEIBULL ANALYSIS ROUTINE

     1.  WEIBULL PARAMETER CALCULATION.  (GE CO)
     2.  PRESENT RISK ANALYSIS.
     3.  FUTURE RISK ANALYSIS.
     4.  WEIBULL FAILURE ANALYSIS - MONTE CARLO ANALYSIS.
     5.  WEIBULL FAILURE ANALYSIS - SHORT PRINT-OUT.
     6.  CHARACTERISTIC LIFE CALCULATION.
     7.  CONFIDENCE INTERVAL CALCULATIONS FOR BETA & TIME TO FIRST FAILURE.
     8.  RELIABILITY AND CONFIDENCE INTERVAL FOR RELIABILITY.
     9.  HISTORICAL VALUES OF BETA.
    10.  WEIBULL PARAMETER CALCULATION W/ MAX. LIKELIHOOD VALUES. (PWA CO)
    11.  WEIBULL FAILURE ANALYSIS - FOR OVER 1100 ENGINES/PARTS.
    12.  WEIBAYES - WHEN WEIBULL PLOTS ARE IMPOSSIBLE
    13.  ZERO FAILURE TEST PLAN FOR SUBSTANTIATION TESTING.
    14.  NON-ZERO FAILURE TEST PLAN GENERATION.
    15.  FOR FUTURE USE - NOT YET AVAILABLE.
    16.  FOR FUTURE USE - NOT YET AVAILABLE.
    17.  FOR FUTURE USE - NOT YET AVAILABLE.
    18.  FOR FUTURE USE - NOT YET AVAILABLE.

TO CONTINUE CHOOSE OPTION NO. OR 900 TO QUIT.? 1
```

```
SUSPENDED WEIBULL PARAMETER CALCULATION PROGRAM (GEN ELEC CO)
AS IMPROVED BY J. L. BYERS, CODE 6052, NAVAIRDEVCEN, WARMINSTER, PA   18974


DATA INPUT ------- TYPE IN THE FOLLOWING :

8800 DATA N,K

          WHERE N = THE TOTAL NUMBER IN THE SAMPLE AND
                K = THE NUMBER OF FAILURES

8910 DATA T1,F1,T2,F2,T3,F3,...,ETC.

                WHERE T1 IS THE AGE IN HOURS OF THE FIRST FAILURE
                      F1 IS THE CUMULATIVE COUNT OF THE FIRST FAILURE
                      T2 IS THE AGE IN HOURS OF THE SECOND FAILURE
                      F2 IS THE CUMULATIVE COUNT OF THE SECOND FAILURE, etc.
USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA.
WHEN THE LAST DATA IS ENTERED, INPUT <RUN 2100> TO CONTINUE.
Break in 2000
Ok


8800 DATA 10,10
8910 DATA 85,1,135,2,150,3,150,4,190,5,200,6,200,7,240,8,240,9,250,10



TOTAL NUMBER IN SAMPLE IS  10

TOTAL NUMBER OF FAILURES IS : 10

WEIBULL PLOTTING POSITIONS

CUMM          HOURS          PERCENT
FAIL           AT              AT
COUNT         FAIL            FAIL
  1           85              6.697
  2           135             16.32
  3           150             25.943
  4           150             35.566
  5           190             45.189
  6           200             54.811
  7           200             64.434
  8           240             74.057
  9           240             83.68
  10          250             93.303
```

```
                    PRESENT RISK ANALYSIS
                  WRITTEN BY JAMES L. BYERS
           NAVAL AIR DEVELOPMENT CENTER, CODE 6052
                  WARMINSTER, PA  18974

                         26 FEB 86

DATA INPUT ---------------- ENTER THE FOLLOWING :
4000 DATA B,H

         WHERE B = THE WEIBULL SLOPE 'BETA'
         AND   H = THE CHARACTERISTIC LIFE 'ETA'
4040 DATA N1,T1,N2,T2,...,etc.

         WHERE N1 IS THE NUMBER OF UNITS AT TIME T1
               T1 IS THE OPERATING TIME OF UNITS N1
               N2 IS THE NUMBER OF UNITS AT TIME T2
               T2 IS THE OPERATING TIME OF UNITS N2, etc.

USE ADDITIONAL LINE AS NEEDED TO ADD MORE DATA.
WHEN THE LAST DATA IS ENTERED, INPUT <RUN 75> TO CONTINUE.
Break in 70
Ok




4000 DATA 1.655057,877.3896
4040 DATA 1,20,1,25,1,104,1,153,1,192,1,198,1,200,1,259,1,270,1,296,1,308,1,326,
1,341,1,410,1,437,1,501,1,580,1,594,1,623,1,660,1,677,1,811,1,862,1,904,1,1030
```

PRESENT RISK ANALYSIS

NUMBER OF FAILURES EXPECTED
TO HAVE OCCURRED BASED ON CURRENT
OPERATING TIMES
WRITTEN BY J. L. BYERS
NADC, WARMINSTER, PA 18974

ENG-1 (HPT DISK)

DATA PAIRS USED: (NO. OF UNITS, OPERATING TIME)

1 , 20 , 1 , 25 , 1 , 104 , 1 , 153 , 1 , 192 , 1 , 198 , 1 , 200 , 1 , 259 ,
1 , 278 , 1 , 296 , 1 , 308 , 1 , 326 , 1 , 341 , 1 , 410 , 1 , 437 , 1 , 501 ,
1 , 580 , 1 , 594 , 1 , 623 , 1 , 668 , 1 , 677 , 1 , 811 , 1 , 862 , 1 , 904 ,
1 , 1030 ,

NO. UNITS	TIME	% FAIL	NO. FAILS
1	20	1.913071E-03	1.913071E-03
1	25	2.766431E-03	2.766431E-03
1	104	2.889371E-02	2.889371E-02
1	153	5.402965E-02	5.402965E-02
1	192	7.769585E-02	7.769585E-02
1	198	8.158517E-02	8.158517E-02
1	200	8.289516E-02	8.289516E-02
1	259	.1243061	.1243061
1	278	.1386367	.1386367
1	296	.152588	.152588
1	308	.162073	.162073
1	326	.1765502	.1765502
1	341	.1888217	.1888217
1	410	.2471529	.2471529
1	437	.2705742	.2705742
1	501	.3267104	.3267104
1	580	.3959249	.3959249
1	594	.4080615	.4080615
1	623	.4329996	.4329996
1	668	.4710267	.4710267
1	677	.4785177	.4785177
1	811	.5843443	.5843443
1	862	.6213478	.6213478
1	904	.6503048	.6503048
1	1030	.7285468	.7285468

TOTAL FAILURES = 6.888267

VALUE OF WEIBULL SLOPE BETA IS 1.655057

VALUE OF CHARACTERISTIC LIFE ETA IS 877.3896

```
                     FUTURE RISK ANALYSIS
                  WRITTEN BY JAMES L. BYERS
           NAVAL AIR DEVELOPMENT CENTER, CODE 6052
                   WARMINSTER, PA 18974
                       1 APRIL 1986
DATA INPUT -------------------- ENTER THE FOLLOWING :
4000 DATA B,H
          WHERE B = THE WEIBULL SLOPE 'BETA'
                H = THE CHARACTERISTIC LIFE 'ETA'

4040 DATA MOS,UTR
          WHERE MOS IS THE NUMBER OF MONTHS INTO THE FUTURE
                UTR IS THE MONTHLY UTILIZATION RATE

4049 DATA N1,T1,N2,T2,...,etc.
          WHERE N1 IS THE NUMBER OF UNITS AT TIME T1
                T1 IS THE OPERATING TIME OF UNITS N1
                N2 IS THE NUMBER OF UNITS AT TIME T2
                T2 IS THE OPERATING TIME OF UNITS N2, etc.
USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA.
WHEN THE LAST DATA PAIR IS ENTERED, INPUT <RUN 250> TO CONTINUE.
Break in 230
Ok
```

```
4000 DATA 6.557812,2741.127
4040 DATA 12,80
4049 DATA 54,400,81.500,54,600,162,700,54,800,189,900,270,1000,216,1100,270,1200
,243,1300,189,1400,135,1500,81,1600,54,1700
```

```
INPUT THE NUMBER OF DATA PAIRS JUST ENTERED.? 14
```

```
INPUT THE ENGINE AND/OR COMPONENT NAME? ENG-1 (LPC DISK)
```

FUTURE RISK ANALYSIS
FORECASTED FAILURES OVER THE NEXT 12 MONTHS TIME
UTILIZATION RATE IS 80 HOURS PER MONTH
WRITTEN BY JAMES L. BYERS
NADC, WARMINSTER, PA 18974

ENG-1 (LPC DISK)

NO.UNITS	TIME	% FAIL	NO.FAILS	CUM FAILS
54	1360	0.01004	0.54191	0.54191
81	1460	0.01592	1.28990	1.83181
54	1560	0.02446	1.32075	3.15255
162	1660	0.03648	5.90921	9.06177
54	1760	0.05296	2.85973	11.92150
189	1860	0.07499	14.17324	26.09474
270	1960	0.10372	28.00345	54.09819
216	2060	0.14024	30.29192	84.39011
270	2160	0.18550	50.08423	134.47430
243	2260	0.24008	58.33913	192.81350
189	2360	0.30403	57.46207	250.27550
135	2460	0.37665	50.84838	301.12390
81	2560	0.45633	36.96305	338.08700
54	2660	0.54049	29.18620	367.27320

TOTAL FAILURES = 367.2732

```
WEIBULL RISK ANALYSIS
A MONTE CARLO SIMULATION
WEIBRSK1
WRITTEN BY: JAMES L. BYERS, CODE 6052
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA  18974


ENGINE :ENG-2


BETA VALUES :
 3.55        5


ETA VALUES :
 2741        2100


DATA PAIRS :
NO. ENGS.     INIT. TIME
    5         1000


MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS 7200 HOURS

INSPECTION INTERVAL FOR THIS ANALYSIS IS 2000 HOURS

TIME DURATION OF THIS ANALYSIS IS 120 MONTHS

UTILIZATION RATE IS 60 HOURS PER ENGINE PER MONTH
```

```
######################## DATA PAIR NUMBER 1 ############################

* * * ITERATION NUMBER 1 * * *

                        ENGINE NUMBER 1
 1789.194      2526.486
TIME ON ENGINE IS 1789.194
 2502.464      2097.962
TIME ON ENGINE IS 3789.193
 868.3184      1772.767
TIME ON ENGINE IS 4657.512
 3182.015      1568.29
TIME ON ENGINE IS 6225.802
 1399.672      2753.114
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 3
NUMBER OF FAILURES FOR ENGINE 1 = 3

                        ENGINE NUMBER 2
 2764.727      2345.466
TIME ON ENGINE IS 2000
 1795.113      796.6212
TIME ON ENGINE IS 2796.621
 2926.716      1805.93
TIME ON ENGINE IS 4602.552
 2434.131      2073.365
TIME ON ENGINE IS 6602.552
 3213.563      2010.636
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 5
NUMBER OF FAILURES FOR ENGINE 2 = 2

                        ENGINE NUMBER 3
 2818.613      1430.67
TIME ON ENGINE IS 1430.67
 1862.299      2149.481
TIME ON ENGINE IS 3292.969
 2715.163      2041.061
TIME ON ENGINE IS 5292.969
 1935.543      2259.948
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 7
NUMBER OF FAILURES FOR ENGINE 3 = 2

                        ENGINE NUMBER 4
 1363.708      1658.388
TIME ON ENGINE IS 1363.708
 1926.678      2429.834
TIME ON ENGINE IS 3290.386
 2087.323      2317.798
TIME ON ENGINE IS 5290.386
 2042.098      2144.922
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 9
NUMBER OF FAILURES FOR ENGINE 4 = 2
```

```
                    ENGINE NUMBER 5
 2039.05       1725.121
TIME ON ENGINE IS 1725.121
 2532.745      1647.712
TIME ON ENGINE IS 3372.833
 2204.548      2368.714
TIME ON ENGINE IS 5372.833
 3726.558      1641.383
TIME ON ENGINE IS 7014.217
 3371.55       1311.027
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 12
NUMBER OF FAILURES FOR ENGINE 5 = 3


TOTAL FAILURES ITERATION NUMBER 1 = 12
             * * * ITERATION NUMBER 2 * * *


                    ENGINE NUMBER 1
 1591.049      1399.003
TIME ON ENGINE IS 1399.003
 1883.363      1804.091
TIME ON ENGINE IS 3203.093
 2431.61       2247.773
TIME ON ENGINE IS 5203.094
 2650.185      2311.475
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 14
NUMBER OF FAILURES FOR ENGINE 1 = 2

                    ENGINE NUMBER 2
 3795.731      1689.961
TIME ON ENGINE IS 1689.961
 2143.793      2234.63
TIME ON ENGINE IS 3689.961
 3051.206      1530.862
TIME ON ENGINE IS 5220.823
 3474.714      1992.701
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 16
NUMBER OF FAILURES FOR ENGINE 2 = 2

                    ENGINE NUMBER 3
 1860.066      2039.179
TIME ON ENGINE IS 1860.066
 2903.865      1867.096
TIME ON ENGINE IS 3727.162
 3424.344      2344.036
TIME ON ENGINE IS 5727.162
 2449.924      2281.253
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 18
NUMBER OF FAILURES FOR ENGINE 3 = 2
```

ENGINE NUMBER 4

```
 4038.293       1767.538
TIME ON ENGINE IS 1767.538
 3105.572       1990.626
TIME ON ENGINE IS 3758.163
 4437.742       2108.566
TIME ON ENGINE IS 5758.163
 2945.658       2489.586
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 20
NUMBER OF FAILURES FOR ENGINE 4 = 2
```

ENGINE NUMBER 5

```
 2696.82        2605.561
TIME ON ENGINE IS 2000
 559.491        1744.22
TIME ON ENGINE IS 2559.491
 3186.987       1452.097
TIME ON ENGINE IS 4011.589
 1764.242       2147.599
TIME ON ENGINE IS 5775.83
 2097.400       1657.036
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 23
NUMBER OF FAILURES FOR ENGINE 5 = 3


TOTAL FAILURES ITERATION NUMBER 2 = 11
                    * * * ITERATION NUMBER 3 * * *
```

ENGINE NUMBER 1

```
 1843.596       2177.372
TIME ON ENGINE IS 1843.596
 1697.332       1576.248
TIME ON ENGINE IS 3419.844
 1681.981       2232.434
TIME ON ENGINE IS 5101.825
 2770.21        1532.093
TIME ON ENGINE IS 6633.918
 1931.305       2164.764
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 27
NUMBER OF FAILURES FOR ENGINE 1 = 4
```

```
                                        ENGINE NUMBER 2
 2324.985      1626.472
TIME ON ENGINE IS 1626.472
 1570.204      1476.156
TIME ON ENGINE IS 3102.628
 3736.515      1404.983
TIME ON ENGINE IS 4507.611
 2222.923      2715.849
TIME ON ENGINE IS 6507.611
 1285.774      1766.777
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 30
NUMBER OF FAILURES FOR ENGINE 2 = 3

                                        ENGINE NUMBER 3
 2000.206      2393.969
TIME ON ENGINE IS 2000
 3588.738      1956.079
TIME ON ENGINE IS 3956.079
 3211.72       1803.588
TIME ON ENGINE IS 5759.667
 1556.806      2447.896
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 32
NUMBER OF FAILURES FOR ENGINE 3 = 2

                                        ENGINE NUMBER 4
 1671.954      1317.436
TIME ON ENGINE IS 1317.436
 1960.408      1676.919
TIME ON ENGINE IS 2994.355
 2157.1        2214.229
TIME ON ENGINE IS 4994.355
 4579.126      1826.355
TIME ON ENGINE IS 6820.711
 2024.263      1706.703
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 35
NUMBER OF FAILURES FOR ENGINE 4 = 3

                                        ENGINE NUMBER 5
 2175.164      1789.512
TIME ON ENGINE IS 1789.512
 2464.898      2034.891
TIME ON ENGINE IS 3789.512
 1397.049      2238.268
TIME ON ENGINE IS 5186.561
 3290.485      1589.487
TIME ON ENGINE IS 6776.047
 1945.26       1496.116
TIME ON ENGINE IS 7200
CUMULATIVE FAILURES FOR THIS DATA PAIR ARE 38
NUMBER OF FAILURES FOR ENGINE 5 = 3


TOTAL FAILURES ITERATION NUMBER 3 = 15
```

```
AVERAGE NUMBER FAILURES 3 ITERATIONS =  12.66667

NUMBER OF FAILURES IN ITERATION 1 = 12

NUMBER OF FAILURES IN ITERATION 2 = 11

NUMBER OF FAILURES IN ITERATION 3 = 15

AVERAGE NUMBER OF FAILURES FOR ENGINE 1 IS 3
AVERAGE NUMBER OF FAILURES FOR ENGINE 2 IS 2.333333
AVERAGE NUMBER OF FAILURES FOR ENGINE 3 IS 2
AVERAGE NUMBER OF FAILURES FOR ENGINE 4 IS 2.333333
AVERAGE NUMBER OF FAILURES FOR ENGINE 5 IS 3
```

WEIBULL RISK ANALYSIS
A MONTE CARLO SIMULATION
SHTWEIB2
WRITTEN BY: JAMES L. BYERS, CODE 6052
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA 18974

ENGINE :ENG-3

BETA VALUES :
3.55

ETA VALUES :
2741

DATA PAIRS :

NO. ENGS.	INIT. TIME
5	1000

MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS 7200 HOURS

INSPECTION INTERVAL FOR THIS ANALYSIS IS 2000 HOURS

TIME DURATION OF THIS ANALYSIS IS 120 MONTHS

UTILIZATION RATE IS 60 HOURS PER ENGINE PER MONTH

```
######################## DATA PAIR NUMBER 1 #############################

AVERAGE NUMBER FAILURES 10 ITERATIONS =  6

NUMBER OF FAILURES IN ITERATION 1 = 9

NUMBER OF FAILURES IN ITERATION 2 = 6

NUMBER OF FAILURES IN ITERATION 3 = 4

NUMBER OF FAILURES IN ITERATION 4 = 8

NUMBER OF FAILURES IN ITERATION 5 = 6

NUMBER OF FAILURES IN ITERATION 6 = 6

NUMBER OF FAILURES IN ITERATION 7 = 5

NUMBER OF FAILURES IN ITERATION 8 = 7

NUMBER OF FAILURES IN ITERATION 9 = 3

NUMBER OF FAILURES IN ITERATION 10 = 6

AVERAGE NUMBER OF FAILURES FOR ENGINE 1 IS 1
AVERAGE NUMBER OF FAILURES FOR ENGINE 2 IS 1.5
AVERAGE NUMBER OF FAILURES FOR ENGINE 3 IS 1.4
AVERAGE NUMBER OF FAILURES FOR ENGINE 4 IS 1.2
AVERAGE NUMBER OF FAILURES FOR ENGINE 5 IS .9
```

```
                    PROGRAM ETACALC
          WRITTEN BY JAMES L. BYERS, CODE 6052
   NAVAL AIR DEVELOPMENT CENTER, WARMINSTER, PA 18974


DATA INPUT ------- INPUT DATA AS INSTRUCTED.

TYPE IN THE FOLLOWING DATA STATEMENT TO INPUT THE WEIBULL SLOPE 'BETA'
AND THE TOTAL NUMBER OF FAILURES :
1700 DATA B,T
         WHERE 'B' IS BETA AND 'T' IS THE TOTAL NUMBER OF FAILURES.
         IF THERE ARE NO FAILURES, INPUT 1 FOR T.

THEN TYPE IN THE FOLLOWING STATEMENT TO INPUT THE DATA PAIRS :
1800 DATA N1,T1,N2,T2,...,etc.
         WHERE N1 IS THE NUMBER OF UNITS AT TIME T1, AND
               T1 IS THE OPERATING TIME ON UNITS N1.
               N2 IS THE NUMBER OF UNITS AT TIME T2, AND
               T2 IS THE OPERATING TIME ON UNITS N2, etc.

WHEN ALL DATA HAS BEEN ENTERED, TYPE 'RUN 100' AND <ENTER>.
Break in 60
Ok


1700 DATA 3,531
1800 DATA 40,19138,49,41578,54,59636,44.78536,38,96564,22,111132.48,130206,94,14
5124,38,164920,38,183006,29,201298,39,220112



INPUT THE NUMBER OF DATA PAIRS JUST ENTERED? 12



           CALCULATION OF THE CHARACTERISTIC LIFE ETA
           BASED ON KNOWN FAILURES AND WEIBULL SLOPE BETA
              WRITTEN BY: JAMES L. BYERS, CODE 6052
                 NAVAL AIR DEVELOPMENT CENTER
                    WARMINSTER, PA  18974



DATA PAIRS :               (NO. OF ENGS. AND TIME ON ENGS.)
 40 , 19138 , 48 , 41578 , 54 , 59636 , 44 , 78536 , 38 , 96564 , 22 , 111132 ,
 48 , 130206 , 94 , 145124 , 38 , 164920 , 38 , 183006 , 29 , 201298 , 39 ,
 220112 ,


THE CALCULATED VALUE OF ETA IS 142914.8

THE VALUE OF BETA USED IS 3
```

```
                 CONFIDENCE INTERVAL CALCULATION
                               FOR
                 BETA - ETA - TIME TO FIRST FAILURE
               WRITTEN BY JAMES L. BYERS, CODE 6052
                   NAVAL AIR DEVELOPMENT CENTER
                      WARMINSTER,PA 18974


$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$


THE CONFIDENCE INTERVALS, OR MEASUREMENT OF THE PRECISION OF THE
ESTIMATION OF BETA AND ETA ARE :


                1.999427  <= BETA <=  4.501291
                1667.089  <= ETA  <=  2399.392


FOR BETA AND ETA ESTIMATES OF 3 AND 2000 AND A CONFIDENCE LEVEL OF .9


$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

CONFIDENCE INTERVAL CALCULATION
FOR
TIME TO FIRST FAILURE
WRITTEN BY JAMES L. BYERS, CODE 6052
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA 18974

VERSION OF 03 OCT 1986

VALUE OF BETA USED IS : 3

VALUE OF ETA USED IS : 2000

NUMBER OF FAILURES BETA AND ETA ARE BASED ON IS : 10

ESTIMATED (CALCULATED) VALUE OF TIME TO FIRST FAILURE IS : 800

THE CONFIDENCE INTERVAL, OR MEASUREMENT OF PRECISION OF THE
ESTIMATE OF THE TIME TO FIRST FAILURE IS :

332.9696 <= TIME TO FIRST FAILURE <= 1336.49

THE ESTIMATED VALUE OF TIME TO FIRST FAILURE IS : 800

```
RELIABILITY
CALCULATES RELIABILITY AS A FUNCTION OF TIME
WRITTEN BY JAMES L. BYERS, CODE 6052
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA 18974


THE RELIABILITY AT TIME 800 IS .8521438
THE PROBABILITY OF FAILURE AT THIS TIME IS .1478562


THE VALUES OF BETA AND ETA USED WERE 2 AND 2000



CONFIDENCE INTERVAL CALCULATION
FOR
RELIABILITY
WRITTEN BY JAMES L. BYERS, CODE 6052
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA 18974


VERSION OF 24 FEB 87


.7176721 <= RELIABILITY <=  .9877289


WHERE RELIABILITY IS .938005 FOR BETA = 3 , ETA = 2000 , AND TIME = 800
```

WEIBULL PARAMETER CALCULATION
PRATT & WHITNEY AIRCRAFT - GPD - UTC
AS IMPROVED BY JAMES L. BYERS, CODE 6052
NAVAIRDEVCEN, WARMINSTER, PA 18974

VERSION 18 FEB 1987

POINT	DATA	ORDER	MEDIAN RANK
1	780	1	.109375
2	820	2	.265625
3	910	3	.421875
4	950	4	.578125
5	1050	5	.734375
6	1050	6	.8906249

BETA= 8.808238 ETA= 974.6675

MAXIMUM LIKELIHOOD ESTIMATES FOLLOW:

BETA= 10.61082 ETA= 973.2028

WEIBULL RISK ANALYSIS
A MONTE CARLO SIMULATION
SHTWEIB2

ENGINE :ENG-4

BETA VALUES :
3.55

ETA VALUES :
2741

DATA PAIRS :

NO. ENGS.	INIT. TIME
5	0

MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS 7200 HOURS

INSPECTION INTERVAL FOR THIS ANALYSIS IS 2000 HOURS

TIME DURATION OF THIS ANALYSIS IS 120 MONTHS

UTILIZATION RATE IS 60 HOURS PER ENGINE PER MONTH

\# DATA PAIR NUMBER 1 \#

AVERAGE NUMBER FAILURES 10 ITERATIONS = 4.5

NUMBER OF FAILURES IN ITERATION 1 = 4

NUMBER OF FAILURES IN ITERATION 2 = 5

NUMBER OF FAILURES IN ITERATION 3 = 3

NUMBER OF FAILURES IN ITERATION 4 = 7

NUMBER OF FAILURES IN ITERATION 5 = 4

NUMBER OF FAILURES IN ITERATION 6 = 5

NUMBER OF FAILURES IN ITERATION 7 = 4

NUMBER OF FAILURES IN ITERATION 8 = 4

NUMBER OF FAILURES IN ITERATION 9 = 6

NUMBER OF FAILURES IN ITERATION 10 = 3

WEIBAYES ANALYSIS
WHEN WEIBULL PLOTS ARE IMPOSSIBLE
DUE TO A LACK OF FAILURE DATA
WRITTEN BY JAMES L. BYERS
NAVAL AIR DEVELOPMENT CENTER, CODE 6052
WARMINSTER, PA 18974

LIFE CALCULATION FOR WEIBAYES

PERCENT OF POPULATION ALLOWED TO FAIL = 10 (CALCULATED VALUE).

THE CALCULATED LIFE USING THE INPUT VALUE OF BX IS EQUAL TO 472.3088

IF THIS VALUE IS SMALLER THAN ACCEPTABLE THEN THE CALCULATED VALUE OF ETA (CHARACTERISTIC LIFE) IS TOO SMALL. THIS MAY BE DUE TO A LACK OF SUFFICIENT OPERATING TIME USED IN THE CALCULATION OF ETA. INSUFFICIENT DATA INDICATES A NEED TO EXERCISE CONSERVATISM UNTIL ENOUGH OPERATIONAL EXPERIENCE IS OBTAINED WITHOUT A FAILURE (OR FEW FAILURES) SUCH THAT A HIGHER VALUE OF ETA IS CALCULATED.

BETA USED WAS 3 ETA USED WAS 1000 .

WEIBAYES ANALYSIS
WHEN WEIBULL PLOTS ARE IMPOSSIBLE
DUE TO A LACK OF FAILURE DATA
WRITTEN BY JAMES L. BYERS
NAVAL AIR DEVELOPMENT CENTER, CODE 6052
WARMINSTER, PA 18974

```
DATA INPUT ------------ ENTER THE FOLLOWING:

4000 DATA BX
                WHERE BX = THE PERCENT OF THE POPULATION ALLOWED
                TO FAIL, i.e., 0.001 FOR B.1 LIFE
                DO NOT USE 1.0 OR ANY PERCENT > 0.999999

4040 DATA B,H
                WHERE B = THE ASSUMED VALUE OF THE WEIBULL SLOPE
                'BETA' AND H = THE CALCULATED VALUE OF THE CHARACTERISTIC
                LIFE 'ETA'
WHEN ALL DATA IS ENTERED, INPUT (RUN 1040) TO CONTINUE.
Break in 1046
Ok

4000 DATA 0.10
4040 DATA 3,1000
```

LIFE CALCULATION FOR WEIBAYES

PERCENT OF POPULATION ALLOWED TO FAIL = 10 (CALCULATED VALUE).

THE CALCULATED LIFE USING THE INPUT VALUE OF BX IS EQUAL TO 472.3088

IF THIS VALUE IS SMALLER THAN ACCEPTABLE THEN THE CALCULATED VALUE OF ETA (CHARACTERISTIC LIFE) IS TOO SMALL. THIS MAY BE DUE TO A LACK OF SUFFICIENT OPERATING TIME USED IN THE CALCULATION OF ETA. INSUFFICIENT DATA INDICATES A NEED TO EXERCISE CONSERVATISM UNTIL ENOUGH OPERATIONAL EXPERIENCE IS OBTAINED WITHOUT A FAILURE (OR FEW FAILURES) SUCH THAT A HIGHER VALUE OF ETA IS CALCULATED.

BETA USED WAS 3   ETA USED WAS 1000 .

ZERO FAILURE TEST PLAN GENERATION
NUMBER OF TEST UNITS AND TEST TIME FOR EACH
WRITTEN BY
WRITTEN BY: JAMES L. BYERS, CODE 6052
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA 18974

VERSION 17 MAY 87

THE TEST PLAN CONSISTS OF THE FOLLOWING:

SAMPLE SIZE IS 19

TEST HOURS ARE 1000

IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE FAILURE MODE WHERE

BETA = 3 AND ETA = 2000

HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED.
THE TEST TIME IS 50 PERCENT OF THE CHARACTERISTIC LIFE OF 2000 HOURS.

SECOND ESTIMATE OF TEST HOURS

THE TEST PLAN CONSISTS OF THE FOLLOWING:

SAMPLE SIZE IS 4

TEST HOURS ARE 1800

IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE FAILURE MODE WHERE

BETA = 3 AND ETA = 2000

HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED.
THE TEST TIME IS 90 PERCENT OF THE CHARACTERISTIC LIFE OF 2000 HOURS.

ALTERNATE TEST PLAN METHOD

THE ALTERNATE TEST PLAN METHOD REQUIRES THE INPUT OF A REASONABLE NUMBER OF UNITS FOR TEST (SAMPLE SIZE) AND THE SELECTION OF A TEST HOUR RATIO FROM THE FOLLOWING TABLE. MAKE AN ESTIMATE OF A REASONABLE SAMPLE SIZE? 1000

NOW CHOOSE THE NEAREST VALUE OF THE WEIBULL SLOPE BETA AND THE SAMPLE SIZE YOU JUST ESTIMATED AND THEN NOTE THE CORRESPONDING TEST HOUR RATIO.

PRESS ENTER TO CONTINUE?

THE TEST PLAN NOW CONSISTS OF THE FOLLOWING:

SAMPLE SIZE IS 1000

TEST HOURS ARE 1832

IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE FAILURE MODE WHERE

BETA = 3   AND   ETA = 2000

HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED.

THE TEST TIME IS 91.6 PERCENT OF THE CHARACTERISTIC LIFE OF 2000 HOURS.

HISTORICAL BETA VALUES

While there are no guaranteed values of Weibull parameters that can be used in any Weibull analysis, there are values of the Weibull slope Beta that seem to occur frequently as nearly constant values for certain classes of failures. In some cases these will be given as a range of values to more accurately reflect how they occur. Even if these values cannot be counted on to be exact, they can be used as a starting point, especially when there is very little data available to calculate Beta with the SUSWEIBL code. If one performs a lot of Weibull analyses, all values of Beta that are validated should be retained in a library for future reference. In addition, as more failure data becomes available for any specific analysis, the analysis should be updated to include the new data. This is especially true of the calculation of Beta and the characteristic life Eta.

The following is a list of Beta values that have been obtained from the references and actual problems:

FAILURE MODE	BETA VALUE
1. Bearings, general failures	1.5
2. Crack, flange	9.5
3. Erosion, turbine vane	3.0
4. LCF, compressor case	5.0
5. LCF, compressor disk	3.0
6. LCF, nozzle bearing	1.5
7. LCF, general	2.0-->5.0
8. Performance deterioration	4.0-->5.0
9. Rotating structure	6.0-->8.0
10. Static structure	4.0-->6.0
11. Thermal LCF, combustor	3.0
12. The following cases all have the same value: Independence of time; Ingestion (FOD) & misuse; Insufficient redundancy; Maintenance errors; Mixtures of problems; Original design deficiencies; Random failures	1.0

The value of the Weibull slope also has the following meanings or indications:

* Slopes less than 1.0 are infant mortality where the reliability will increase with age. It also indicates a quality problem such as misassembly (slope usually about 0.5).

* Slopes that are greater than 1.0 are generally wearout for one reason or another.

* A slope of approximately 2.5 is usually gradual wearout.

* A slope of 3.44 approximates the bell-shaped curve of a Normal distribution.

*Slopes that are greater than about 4.5 are usually rapid wearout (brick wall).

REFERENCES

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b. Abernethy, DR. R. B., J. E. Breneman, C. H. Medlin, and G. L. Reinman, "WEIBULL ANALYSIS HANDBOOK," PWA, GPD, and Air Force Wright Aeronautical Laboratory, Final Report, AFWAL-TR-83-2079, November 1983.

c. Daub, W. J., "WEIBULL ANALYSIS FOR AIRCRAFT ENGINE COMPONENTS," General Electric Company, undated.

d. Caporal, P. M., "An Introduction to the Weibull Distribution," General Electric Company, 20 June 1895

e. Monahan, M. H., and E. R. Hutsell, "A Simplified Method of Weibull Analysis of Field or Test Data: Time Share," General Electric Company, AEG, Lynn, MA, undated

f. Cyrus, J. D., "Engine Component Life Prediction Methodology for Conceptual Design Investigations," ASME Paper 86-GT-24,June 1986

g. Zaretsky, E. V., "Fatigue Criterion to System Design, Life and Reliability," AIAA Paper, AIAA-85-1140, July 1985

h. Burkett, M. A., "Reliability Assessment from Small Sample Inspection Data for Gas Turbine Engine Components," SAE Paper, 841599, October, 1984

APPENDIX A

PROGRAM LISTING

The following pages contain the listings of all the codes and WEIBER, the Weibull Executive Routine. These listings are presented in the same order as they are listed in the Weiber main menu.

```
5     REM
10    REM $$$$$$$$$$$$$$$$$$$$ PROGRAM WEIBCOVR $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
12    KEY OFF
14    COLOR 2,0,0
16    WIDTH 40
20    CLS:PRINT:PRINT:PRINT:PRINT:PRINT:PRINT"          WELCOME TO WEIBER"
22    PRINT:PRINT:PRINT:PRINT:PRINT"    YOU CAN PERFORM RISK ANALYSIS"
24    PRINT:PRINT"                AND":PRINT
26    PRINT"          PREDICT FAILURES"
30    PRINT:PRINT:PRINT"     ARE YOU READY - <Y> OR <N>";:INPUT A$
35    IF A$="Y" THEN CHAIN "WEIBINTR"
36    IF A$="N" THEN 29999
37    IF A$<>"N" THEN 20
29999 CLS:END
30000 CLS:PRINT"SAVING WEIBCOVR ON DISK B":SAVE"B:WEIBCOVR":END
```

```
5   REM
10  REM********************** PROGRAM WEIBINTR ******************************
12  KEY OFF
14  COLOR 2,0,0
16  WIDTH 80
100 PRINT:PRINT:CLS
200 PRINT"                    WEIBULL RISK ANALYSIS ROUTINE":PRINT
300 PRINT"                     WRITTEN BY JAMES L. BYERS"
400 PRINT"                    NAVAL AIR DEVELOPMENT CENTER"
500 PRINT"                             CODE 6052"
600 PRINT"                       WARMINSTER, PA 18974"
700 PRINT
800 PRINT"                         VERSION 2 MAY 1986":PRINT
810 PRINT"                IF YOU HAVE PROBLEMS OR COMMENTS CONTACT"
820 PRINT"              JAMES L. BYERS AT THE ABOVE ADDRESS OR PHONE"

835 PRINT"                              OPTIONS":PRINT
900 PRINT"        * * * FOR MENU -------------------------------TYPE 100 <ENTER
>"
1100 PRINT"        * * * FOR HELP ------------------------------- TYPE 800 <ENTE
R>"
1200 PRINT"        * * * TO QUIT ------------------------------- TYPE 900 <ENTE
R>":PRINT:PRINT:PRINT:PRINT
1250 CLOSE
1300 PRINT"YOUR CHOICE";:INPUT A
1400 IF A=100 THEN CHAIN "WEIBER"
1500 IF A=800 THEN 4100
1600 IF A=900 THEN 29999
1650 IF A<>900 THEN 100
1795 CLS:PRINT"NOT A VALID CHOICE - SEE OPTIONS.":FOR X=1 TO 1500:NEXT X:GOTO 10
0
4000 REM
4100 CLS:PRINT:PRINT:PRINT
4200 PRINT"               * * * HELP FOR WEIBULL ANALYSIS ROUTINE * * *"
4300 PRINT:PRINT
4400 PRINT"     THIS IS A SYSTEMATIC ROUTINE FOR MAKING FAILURE ANALYSES BASED O
N"
4500 PRINT"THE WEIBULL DISTRIBUTION METHODOLOGY.  THE SERIES OF CODES THAT MAKE
UP THE"
4600 PRINT"ROUTINE ARE WRITTEN FOR GAS TURBINE ENGINE PART FAILURES BUT CAN BE"
4700 PRINT"APPLIED TO ANY TYPE EQUIPMENT THAT CORRELATES IN A WEIBULL DISTRIBUTI
ON."
4800 PRINT"     THE FOLLOWING IS A LIST OF THE AVAILABLE CODES AND THEIR FUNCTIO
NS."
4900 PRINT"YOU MAY USE ANY CODE AS A STAND-ALONE ANALYTICAL TOOL.":PRINT:PRINT
5000 PRINT"PRESS ANY KEY TO CONTINUE.";
5100 INPUT Q$:IF Q$<>"" THEN 4100
```

```
5200 CLS:PRINT"     1.  WEIBULL PARAMETER CALCULATION (SUSWEIBL) - THIS CODE IS
USED TO"
5300 PRINT"CALCULATE THE WEIBULL SLOPE 'BETA' AND THE CHARACTERISTIC LIFE 'ETA'"
5400 PRINT"USING A SAMPLE COMPOSED OF BOTH FAILURES AND SUSPENDED UNITS.  SUSPEN
DED"
5500 PRINT"UNITS ARE THOSE THAT ARE NON-FAILED OR NOT FAILED BY THE MODE UNDER"
5600 PRINT"CONSIDERATION.  DATA REQUIRED ARE: (1) NUMBER OF UNITS IN THE SAMPLE,
"
5700 PRINT"(2) NUMBER OF FAILED UNITS IN THE SAMPLE, AND (3) NUMBER AND AGE OF E
ACH"
5800 PRINT"UNIT OR GROUP OF UNITS WITH THE SAME AGE.  THE OUTPUT FROM THIS CODE"
5900 PRINT"IS : (1) BETA, (2) ETA, (3) B-10 LIFE, (4) B-50 LIFE, (5) LEAST SQUAR
ES"
6000 PRINT"CORRELATION COEFFICIENT, AND (6) THE INSTANTANEOUS FAILURE RATE VERSU
S"
6100 PRINT"THE AGE OF THE UNITS.  IF BETA IS KNOWN, OR IF YOU HAVE A GOOD ESTIMA
TE"
6200 PRINT"OF BETA, YOU MAY USE OPTION 6, 'CHARACTERISTIC LIFE CALCULATION.'"
6300 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
6400 INPUT Q$:IF Q$<>"" THEN 5200
6500 CLS:PRINT"     2.  PRESENT RISK ANALYSIS (PRESRISK) - THIS CODE IS USED TO
CALCULATE"
6600 PRINT"THE EXPECTED NUMBER OF FAILURES TO HAVE OCCURRED TO DATE OVER THE LIF
E OF"
6700 PRINT"THE UNITS OF THE SAMPLE.  THE CODE IS EXCELLENT FOR VERIFYING THE FAI
LURES"
6800 PRINT"AS WELL AS 'ETA' BY COMPARING ANSWERS WITH KNOWN FAILURES IN THE POPU
LATION."
6900 PRINT"DATA REQUIRED ARE; (1) BETA, (2) ETA, (3) NUMBER AND AGE OF EACH UNIT
 OR"
7000 PRINT"GROUP OF UNITS WITH THE SAME AGE.  THE OUTPUT FROM THE CODE IS:"
7100 PRINT"(1) THE PERCENT IN EACH GROUP EXPECTED TO FAIL, (2) THE NUMBER IN EAC
H GROUP"
7200 PRINT"EXPECTED TO FAIL, AND (3) THE TOTAL NUMBER OF EXPECTED FAILURES FOR T
HE"
7300 PRINT"POPULATION."
7400 PRINT:PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";:INPUT Q$:IF Q$<>
"" THEN 6500
7500 CLS:PRINT"     3.  FUTURE RISK ANALYSIS (FUTRISKS) - THIS CODE IS USED TO C
ALCULATE"
7600 PRINT"THE EXPECTED NUMBER OF FAILURES OVER A SPECIFIED FUTURE TIME PERIOD F
OR"
7700 PRINT"A POPULATION THAT ACCUMULATES MORE OPERATING TIME OVER THAT TIME PERI
OD."
7800 PRINT"IT IS ASSUMED THAT THERE ARE NO REPAIRS SO FAILURES ARE FOR THE ORIGI
NAL"
7900 PRINT"POPULATION ONLY.  FOR A MORE COMPLEX ANALYSIS WHERE PARTS ARE REPAIRE
D"
8000 PRINT"AND RETURNED TO SERVICE, SEE OPTION 4, THE MONTE CARLO RISK ANALYSIS.
"
8100 PRINT"DATA REQUIRED ARE: (1) BETA, (2) ETA, (3) MONTHS INTO THE FUTURE THAT
 THE"
8200 PRINT"ANALYSIS WILL COVER, (4) AVERAGE MONTHLY OPERATING HOURS PER UNIT OVE
R"
8300 PRINT"THE TIME PERIOD, AND (5) NUMBER AND AGE OF EACH GROUP OF UNITS WITH T
HE SAME"
8400 PRINT"AGE.  THE OUTPUT FROM THIS CODE IS: (1) THE PERCENT IN EACH GROUP EXP
ECTED"
```

```
8500 PRINT"TO FAIL, (2) THE NUMBER IN EACH GROUP EXPECTED TO FAIL, (3) CUMULATIV
E"
8600 PRINT"FAILURES, AND (4) THE TOTAL NUMBER OF EXPECTED FAILURES IN THE POPULA
TION."
8700 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
8800 INPUT Q$:IF Q$<>"" THEN 7500
8900 CLS:PRINT"     4.  WEIBULL FAILURE ANALYSIS - MONTE CARLO (WEIBRISK) - THIS
 CODE IS"
9000 PRINT"A COMPREHENSIVE ANALYTICAL TOOL THAT CAN BE USED TO FORECAST NUMBERS
OF"
9100 PRINT"FAILURES AS WELL AS THE FAILURE TIMES IN TERMS OF OPERATING HOURS OR
CYCLES."
9200 PRINT"IT IS A STATISTICAL CODE THAT MAKES THOUSANDS OF CALCULATIONS TO ALLO
W"
9300 PRINT"STATISTICAL AVERAGES TO BE CALCULATED.  IT IS EXTREMELY ACCURATE WHEN
"
9400 PRINT"REQUIRED INPUT DATA IS EXTREMELY ACCURATE.  IT IS CAPABLE OF PROVIDIN
G"
7500 PRINT"SENSITIVITIES SO THAT LESS ACCURATE DATA CAN BE USED TO ARRIVE AT"
9600 PRINT"REASONABLE SOLUTIONS AND ALLOW FOR IMPACT ANALYSIS.  DATA REQUIRED AR
E:"
9700 PRINT"(1) BETA, (2) ETA, (3) NUMBER AND AGE OF EACH GROUP OF UNITS WITH THE
 SAME      INITIAL TIME, (4) TOTAL NUMBER OF ENGINES IN THE SAMPLE, (5) NUMBER O
F MONTHS   IN THE ANALYSIS, (6) AVERAGE OPERATING HOURS PER MONTH PER PART OVER
THE TIME"
9800 PRINT"OF THE ANALYSIS, (7) THE INSPECTION INTERVAL AT WHICH, IF REACHED BEF
ORE A"
9900 PRINT"FAILURE OCCURS, ALL PARTS CONSIDERED ARE MADE GOOD-AS-NEW OR ZERO-TIM
ED,"
10000 PRINT"(8) NUMBER OF FAILURE MODES IN THE ANALYSIS, AND (9) THE ENGINE NAME
."
10100 PRINT"NOTE THAT BETA AND ETA MUST BE FURNISHED FOR EACH FAILURE MODE.  ALS
O"
10200 PRINT"NOTE THAT LARGE NUMBERS OF ENGINES AND MULTIPLE FAILURE MODES GREATL
Y"
10300 PRINT"INCREASE THE RUNNING TIME.  THE OUTPUT FROM THIS CODE IS: (1) FAILUR
E TIMES"
10400 PRINT"(2) NEW FAILURE TIMES, (3) NUMBER OF FAILURES PER ENGINE, (4) IDENTI
FICATION OF FAILURE MODE, (5) AVERAGE NUMBER OF FAILURES PER ENGINE OVER THE NUM
BER OF      ITERATIONS, (6) CUMULATIVE FAILURES PER ENGINE, AND (7) AVERAGE FAIL
URES"
10500 PRINT"FOR ALL ENGINES FOR ALL ITERATIONS."
10600 PRINT:PRINT:PRINT"PRESS ENTER KEY TO CONTINUE.";
10700 INPUT Q$:IF Q$<>"" THEN 8900
10800 CLS:PRINT"     5.  WEIBULL FAILURE ANALYSIS - SHORT PRINT-OUT (SHRTWEIB) -
 THIS CODE"
10900 PRINT"IS ALMOST IDENTICAL TO THE PREVIOUS CODE EXCEPT FOR THE AMOUNT OF OU
TPUT."
11000 PRINT"IN ORDER TO SPEED UP THE ANALYSIS, ONLY NUMBERS OF FAILURES ARE OUTP
UT"
11100 PRINT"AND FAILURE TIMES AND MODES OF FAILURE ARE ELIMINATED.  THIS CODE IS
"
11200 PRINT"VERY USEFUL AFTER IT HAS BEEN DETERMINED WHICH FAILURE MODES DOMINAT
E"
11300 PRINT"AND SHEER NUMBERS ARE OF PRIME INTEREST.  MANY MORE ENGINES MAY BE A
NALYSED"
11400 PRINT"IN THE SAME AMOUNT OF TIME AND THE VOLUME OF PAPER GENERATED IS VERY
"
```

```
11500 PRINT"SIGNIFICANTLY LESS."
11600 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
11700 INPUT A$:IF A$<>"" THEN 10800
11800 CLS:PRINT"     6.  CHARACTERISTIC LIFE CALCULATION (ETACALC) - THIS CODE I
S USEFUL"
11900 PRINT"WHEN BETA IS KNOWN FOR THE FAILURE MODE AND GOOD FAILURE DATA IS AVA
ILABLE"
12000 PRINT"TO CALCULATE ONLY THE CHARACTERISTIC LIFE.  DATA REQUIRED ARE: (1) B
ETA,"
12100 PRINT"(2) TOTAL NUMBER OF FAILURES THAT DATA IS AVAILABLE FOR, AND (3) DAT
A"
12200 PRINT"PAIRS OF NUMBERS OF FAILURES AND OPERATING TIME AT FAILURE.  THE OUT
PUT"
12300 PRINT"FROM THIS CODE IS THE CALCULATED VALUE OF THE CHARACTERISTIC LIFE."
12400 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12410 INPUT A$:IF A$<>"" THEN 11800
12420 CLS:PRINT"     7.  CONFIDENCE INTERVAL CALCULATION (CNFINTBE) - THIS CODE
CALCULATES"
12430 PRINT"UPPER AND LOWER CONFIDENCE BOUNDS FOR BOTH BETA AND TIME TO FIRST FA
ILURE."
12440 PRINT"CALCULATIONS CAN BE MADE FOR CONFIDENCE LEVELS OF 0.90, 0.95, OR 0.9
9."
12450 PRINT"THESE UPPER & LOWER LIMITS ARE INDICATIONS OF THE ACCURACY ONE CAN E
XPECT"
12460 PRINT"FROM THE MANY CALCULATIONS THAT CAN BE MADE FROM THESE CODES."
12470 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12480 INPUT Q$:IF Q$<>"" THEN 12420
12500 CLS:PRINT"     8.  RELIABILITY AND CONFIDENCE INTERVALS FOR RELIABILITY (R
ELIABTY) -"
12510 PRINT"THIS CODE CALCULATES THE RELIABILITY OF A COMPONENT AT ANY TIME BASE
D ON"
12520 PRINT"THE VALUES OF BETA AND ETA.  YOU MAY THEN CALCULATE THE CONFIDENCE I
NTERVAL"
12530 PRINT"FOR THIS RELIABILITY AT A CONFIDENCE LEVEL OF 0.90, 0.95, OR 0.99."
12532 PRINT"ALSO PRESENTED IS THE CORRESPONDING PROBABILITY OF FAILURE."
12540 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12550 INPUT Q$:IF Q$<>"" THEN 12500
12600 CLS:PRINT"     9.  HISTORICAL BETA VALUES (BETAHIST) - THIS CODE PRINTS OU
T A LIST OF"
12610 PRINT"PROBABLE VALUES OR RANGES OF BETA FOR SOME COMMON MODES OF FAILURE I
N GAS"
12620 PRINT"TURBINE COMPONENTS.  WHILE THESE HISTORICAL VALUES SHOULD NOT BE TAK
EN AS"
12630 PRINT"ABSOLUTE, THEY REPRESENT REASONABLE STARTING VALUES, ESPECIALLY FOR
PERFORMING"
12640 PRINT"SENSITIVITY ANALYSES."
12650 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12660 INPUT Q$:IF Q$<>"" THEN 12600
12700 CLS:PRINT"     10.  WEIBULL PARAMETER CALCULATION (PWA CO) - THIS CODE IS
SIMILAR TO"
12710 PRINT"CODE NUMBER 1 EXCEPT THAT IT CAN PROVIDE THE VALUES OF BETA AND ETA
WHICH"
12720 PRINT"MAXIMIZE THE 'LIKELIHOOD' OF OBTAINING THE OBSERVED DATA.  THERE ARE
 CASES"
12730 PRINT"WHERE THESE VALUES MAY BE DIFFERENT THAN THOSE OBTAINED IN CODE 1 BY
 A"
12740 PRINT"REASONABLE AMOUNT.  IF THERE IS A QUESTION, BOTH CODES SHOULD BE RUN
 AND"
```

```
12750 PRINT"SENSITIVITIES ESTABLISHED."
12752 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12753 INPUT A$:IF A$<>"" THEN 12700
12755 CLS:PRINT"     11.  WEIBULL FAILURE ANALYSIS FOR OVER 1100 ENGINES/PARTS -
"
12760 PRINT"THIS CODE IS SIMILAR TO THE PREVIOUS TWO MONTE CARLO CODES EXCEPT TH
AT"
12765 PRINT"IT IS OPTIMIZED TO ANALYZE A MAXIMUM OF ENGINES/PARTS.  THIS CODE SH
OULD"
12770 PRINT"BE USED AFTER THE DOMINANT FAILURE MODE HAS BEEN DETERMINED AND NO M
ORE"
12775 PRINT"THAN ONE FAILURE MODE SHOULD BE ANALYZED AT A TIME.  THE INPUT IS TH
E SAME"
12780 PRINT"AS IN CODES (4) AND (5) BUT THE OUTPUT IS LIMITED TO THAT OF CODE (5
)."
12785 PRINT"ONLY THE TOTAL FAILURES ARE GIVEN PER ITERATION ALONG WITH THE AVERA
GES."
12790 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12795 INPUT A$:IF A$<>"" THEN 12755
12800 CLS:PRINT"     12.  WEIBAYES, WHEN WEIBULL PLOTS ARE NOT POSSIBLE -"
12805 PRINT"WHEN THERE IS INSUFFICIENT FAILURE DATA TO CALCULATE THE WEIBULL SLO
PE BETA"
12810 PRINT"AND THE CHARACTERISTIC LIFE ETA WE MAY MAKE ASSUMPTIONS TO ARRIVE AT
 THE"
12815 PRINT"BEST ESTIMATES AND MAKE CALCULATIONS TO DETERMINE THE DESIRED LIFE,
i.e.,"
12820 PRINT"B.1, B1, B10, OR B50 LIFE.  FIRST, IT IS NECESSARY TO MAKE THE BEST
GUESS"
12825 PRINT"REGARDING THE FAILURE MODE SUCH AS LCF, HCF, OR OTHERS.  THEN USE CO
DE"
12830 PRINT"(6), CHARACTERISTIC LIFE CALCULATION, TO DETERMINE A BEST ESTIMATE O
F ETA."
12835 PRINT"THESE FORM THE INPUT FOR THIS CODE WHICH THEN CALCULATES THE APPROPR
IATE"
12840 PRINT"LIFE OF THE PART IN QUESTION."
12845 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12850 INPUT A$:IF A$<>"" THEN 12800
12855 CLS:PRINT"     13.  ZERO-FAILURE TEST PLAN FOR SUBSTATIATION TESTING -"
12860 PRINT"THIS CODE CALCULATES THE NUMBER OF ENGINES/PARTS THAT MUST BE TESTED
 WITHOUT"
12865 PRINT"FAILURE IN ORDER TO DEMONSTRATE THAT A GIVEN FAILURE MODE HAS BEEN E
ITHER"
12870 PRINT"ELIMINATED OR SUBSTANTIALLY IMPROVED.  INPUTS REQUIRED ARE (1) WEIBU
LL SLOPE"
12875 PRINT"BETA, (2) CHARACTERISTIC LIFE ETA, AND (3) AN ESTIMATE OF A REASONAB
LE"
12880 PRINT"AMOUNT OF TEST TIME, RECOGNIZING THAT AT LEAST THREE PARTS OR MORE M
UST"
12885 PRINT"EACH BE TESTED FOR THAT AMOUNT OF TIME.  THE CODE ALLOWS A SECOND AN
D"
12890 PRINT"THIRD TEST TIME ESTIMATE (OR MORE) AND ALSO PROVIDES FOR AN ALTERNAT
E"
12895 PRINT"METHOD OF TEST PLAN FORMULATION.  THEN TEST PLAN IS OUTPUT IN TERMS
OF"
12900 PRINT"A SAMPLE SIZE, EACH OF WHICH MUST BE TESTED FOR A GIVEN NUMBER OF HO
URS"
12905 PRINT"WITHOUT FAILURE IN ORDER TO DEMONSTRATE A SIGNIFICANT IMPROVEMENT IN
 LIFE."
```

```
12910 PRINT:PRINT:PRINT"PRESS THE ENTER KEY TO CONTINUE.";
12915 INPUT A$:IF A$<>"" THEN 12055
12920 CLS:PRINT"     14.  NON-ZERO FAILURE TEST PLAN GENERATION - THIS CODE IS S
IMILAR"
12925 PRINT"TO THE PREVIOUS CODE EXCEPT THAT IT CALCULATES A TEST PLAN THAT ALLO
WS"
12930 PRINT"FOR FAILURES.  HERE THE GOAL IS TO DEVISE A TEST PLAN TO DEMONSTRATE
 THE"
12935 PRINT"ACHIEVEMENT OF A GIVEN IMPROVEMENT IN A PARTS CHARACTERISTIC LIFE.
THE TEST"
12940 PRINT"IS PASSED IF ALL PARTS ARE RUN FOR A SPECIFIED NUMBER OF TEST HOURS
"
12945 PRINT"(OR CYLES) WITH NO MORE THAN A CALCULATED NUMBER OF FAILURES.  INPUT
 CONSISTS"
12950 PRINT"OF (1) CURRENT CHARACTERISTIC LIFE ETA, (2) CHARACTERISTIC LIFE WITH
 AN"
12955 PRINT"IMPROVED PART OR FIX, (3) THE WEIBULL SLOPE BETA FOR THE FAILURE MOD
E,"
12960 PRINT"AND (4) A REASONABLE ESTIMATE OF TEST HOURS FOR EACH TEST ARTICLE."
12965 PRINT"OUTPUT CONSISTS OF A SAMPLE SIZE, THE NUMBER OF TEST HOURS FOR EACH
PART"
12970 PRINT"AND THE NUMBER OF FAILURES ALLOWED FOR A SUCCESSFUL TEST."
13790 PRINT:PRINT:PRINT
13800 PRINT"PRESS THE ENTER KEY TO RETURN TO THE OPTIONS MENU.";
13900 INPUT A$:IF A$<>"" THEN CLS:GOTO 13800
14000 CLS:GOTO 100
29998 END
29999 CLS:END
30000 CLS:PRINT"SAVING WEIBINTR ON DISK B":SAVE "B:WEIBINTR":END
```

```
5   REM
7    WIDTH 80
10  REM********************* PROGRAM WEIBER ********************************
12  KEY OFF
14  COLOR 6,0,0
100 CLS
150 GOTO 2800
1200 IF A=900 GOTO 29999
1705 IF A=1 THEN 1800
1710 IF A=2 THEN 1900
1715 IF A=3 THEN 2000
1720 IF A=4 THEN 2100
1725 IF A=5 THEN 2200
1730 IF A=6 THEN 2300
1735 IF A=7 THEN 2400
1740 IF A=8 THEN 2500
1745 IF A=9 THEN 2600
1750 IF A=10 THEN 2700
1755 IF A=11 THEN 2720
1760 IF A=12 THEN 2710
1765 IF A=13 THEN 2712
1768 IF A=14 THEN 2714
1771 IF A=15 THEN 2750
1774 IF A=16 THEN 2760
1777 IF A=17 THEN 2765
1780 IF A=18 THEN 2770
1785 IF A<>18 THEN 1795
1795 CLS:PRINT"NOT A VALID CHOICE - SEE MENU.":FOR Y=1 TO 5:BEEP:NEXT Y:FOP X=1
TO 1500:NEXT X:GOTO 2800
1800 CHAIN "SUSWEIBL"
1900 CHAIN "PRESRISK"
2000 CHAIN "FUTRISKS"
2100 CHAIN "WEIBRSK1"
2200 CHAIN "SHTWEIB2"
2300 CHAIN "ETACALC"
2400 CHAIN "CNFINTBE"
2500 CHAIN "RELIABTY"
2600 CHAIN "BETAHIST"
2700 CHAIN "PWAWEIBL"
2710 CHAIN "WEIBAYES"
2712 CHAIN "ZOFAILSB"
2714 CHAIN "NZFTESTP"
2720 CHAIN "BIGWEIBL"
2750 CHAIN "DATAFILE"
2755 CLS:PRINT"MAKE ANOTHER CHOICE - SEE MENU.":FOR X=1 TO 1500:NEXT X:GOTO 2800
2760 CLS:PRINT"MAKE ANOTHER CHOICE - SEE MENU.":FOR X=1 TO 1500:NEXT X:GOTO 2000
2765 CLS:PRINT"MAKE ANOTHER CHOICE - SEE MENU.":FOR X=1 TO 1500:NEXT X:GOTO 2800
2770 CLS:PRINT"MAKE ANOTHER CHOICE - SEE MENU.":FOR Y=1 TO 5:BEEP:NEXT Y:FOR X=1
TO 1500:NEXT X:GOTO 2800
```

```
2800 CLS:PRINT"                                  MENU"
2900 PRINT"                        WEIBULL ANALYSIS ROUTINE":PRINT
3000 PRINT"     1.  WEIBULL PARAMETER CALCULATION.  (GE CO)"
3100 PRINT"     2.  PRESENT RISK ANALYSIS."
3200 PRINT"     3.  FUTURE RISK ANALYSIS."
3300 PRINT"     4.  WEIBULL FAILURE ANALYSIS - MONTE CARLO ANALYSIS."
3400 PRINT"     5.  WEIBULL FAILURE ANALYSIS - SHORT PRINT-OUT."
3500 PRINT"     6.  CHARACTERISTIC LIFE CALCULATION."
3600 PRINT"     7.  CONFIDENCE INTERVAL CALCULATIONS FOR BETA & TIME TO FIRST FA
ILURE."
3700 PRINT"     8.  RELIABILITY AND CONFIDENCE INTERVAL FOR RELIABILITY."
3800 PRINT"     9.  HISTORICAL VALUES OF BETA."
3900 PRINT"    10.  WEIBULL PARAMETER CALCULATION W/ MAX. LIKELIHOOD VALUES. (PW
A CO)"
3902 PRINT"    11.  WEIBULL FAILURE ANALYSIS - FOR OVER 1100 ENGINES/PARTS."
3905 PRINT"    12.  WEIBAYES - WHEN WEIBULL PLOTS ARE IMPOSSIBLE"
3906 PRINT"    13.  ZERO FAILURE TEST PLAN FOR SUBSTANTIATION TESTING."
3910 PRINT"    14.  NON-ZERO FAILURE TEST PLAN GENERATION."
3915 PRINT"    15.  WEIBULL PARAMETER CALCULATION AND SAVE INPUT DATA  (PWA)"
3920 PRINT"    16.  FOR FUTURE USE - NOT YET AVAILABLE."
3925 PRINT"    17.  FOR FUTURE USE - NOT YET AVAILABLE."
3930 PRINT"    18.  FOR FUTURE USE - NOT YET AVAILABLE."
3980 PRINT:PRINT"TO CONTINUE CHOOSE OPTION NO. OR 900 TO QUIT.";:INPUT  A:GOTO 1
200
4000 REM
13790 PRINT:PRINT:PRINT
13800 PRINT"PRESS THE ENTER KEY TO RETURN TO THE MAIN MENU.";
13900 INPUT A$:IF A$<>"" THEN 12700
14000 CLS:GOTO 2800
29998 END
29999 CLS:END
30000 CLS:PRINT"SAVING WEIBER ON DISK B":SAVE "B:WEIBER":END
```

```
10  REM
20  REM ###################### PROGRAM SUSWEIBL ###############################
30  REM
40  REM
45  CLS
200 S2=0
300 S3=0
400 S4=0
500 S5=0
600 PRINT"      SUSPENDED WEIBULL PARAMETER CALCULATION PROGRAM (GEN ELEC CO)
"
700 PRINT" AS IMPROVED BY J. L. BYERS, CODE 6052, NAVAIRDEVCEN, WARMINSTER, PA
 18974"
710 PRINT"            PHONE: (215)441-2326 WORK        (215)672-8792 HOME"
745 LPRINT"      SUSPENDED WEIBULL PARAMETER CALCULATION PROGRAM (GEN ELEC CO)
"
750 LPRINT"                AS IMPROVED BY J. L. BYERS, CODE 6052"
751 LPRINT"                    NAVAL AIR DEVELOPMENT CENTER"
752 LPRINT"                       WARMINSTER, PA 18974"

NT
757 LPRINT"                              18 FEB 86"
760 LPRINT:LPRINT:LPRINT:LPRINT
800 PRINT:PRINT:PRINT
900 PRINT"DATA INPUT ------- TYPE IN THE FOLLOWING :":PRINT
1000 PRINT"8800 DATA N,K":PRINT
1100 PRINT"         WHERE N = THE TOTAL NUMBER IN THE SAMPLE AND"
1200 PRINT"               K = THE NUMBER OF FAILURES"
1300 PRINT:PRINT"8910 DATA T1,F1,T2,F2,T3,F3,...,ETC.":PRINT
1400 PRINT"              WHERE T1 IS THE AGE IN HOURS OF THE FIRST FAILURE"
1500 PRINT"                   F1 IS THE CUMULATIVE COUNT OF THE FIRST FAILURE
"
1600 PRINT"                   T2 IS THE AGE IN HOURS OF THE SECOND FAILURE"
1700 PRINT"                   F2 IS THE CUMULATIVE COUNT OF THE SECOND FAILUR
E, etc."
1800 PRINT"USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA."
1900 PRINT"WHEN THE LAST DATA IS ENTERED, INPUT <RUN 2100> TO CONTINUE."
2000 STOP
2100 CLS
2200 READ N,K
2300 PRINT"TOTAL NUMBER IN SAMPLE IS ";N:PRINT
2400 PRINT"TOTAL NUMBER OF FAILURES IS ";K:PRINT
2500 PRINT"WEIBULL PLOTTING POSITIONS"
2600 PRINT
2700 PRINT "CUMM "," HOURS"," PERCENT"
2800 PRINT "FAIL","  AT","   AT"
2900 PRINT "COUNT"," FAIL","  FAIL"
2950 LPRINT"TOTAL NUMBER IN SAMPLE IS ";N:LPRINT
2955 LPRINT"TOTAL NUMBER OF FAILURES IS :";K:LPRINT
2960 LPRINT"WEIBULL PLOTTING POSITIONS"
2965 LPRINT
2970 LPRINT"CUMM "," HOURS"," PERCENT"
2975 LPRINT"FAIL","  AT","   AT"
2980 LPRINT"COUNT"," FAIL","  FAIL"
3000 CO=-.0001
3100 M=0
3200 FOR I=1 TO K
3300 READ F,C
```

```
3400 IF C-CO=1 THEN 3600
3500 D=(N+1-M)/(N+2-C)
3600 M=M+D
3700 L=(1-(2^(-1/N))+((M-1)/(N-1))*(2^(1-1/N)-1))
3800 L1=INT(100000!*L+.5)/1000
3900 PRINT" " C,F," "L1
3905 LPRINT" " C,F,"  "L1
4000 W=LOG(LOG(1/(1-L)))
4100 Z=LOG(F)
4200 S1=S1+Z
4300 S2=S2+Z*Z
4400 S3=S3+W
4500 S4=S4+W*W
4600 S5=S5+Z*W
4700 CO=C
4800 NEXT I
4850 LPRINT:LPRINT:LPRINT:LPRINT
4900 PRINT:PRINT"PRESS ENTER KEY TO CONTINUE";
5000 INPUT R$
5100 CLS
5200 IF K=1 THEN 8200
5300 N=K
5400 A2=(S2*S3-S1*S5)/(N*S2-S1*S1)
5500 B2=(N*S5-S1*S3)/(N*S2-S1*S1)
5600 S7=SQR((S2-S1*S1/N)/N)
5700 S9=SQR((S4-S3*S3/N)/N)
5800 R1=(S5/N-S1*S3/(N*N))/(S7*S9)
5900 L=EXP(-(A2)/(B2))
6000 M=LOG(LOG(1.1111110))
6100 B3=EXP((M-A2)/B2)
6200 M1=LOG(LOG(2))
6300 B4=EXP((M1-A2)/B2)
6400 PRINT:PRINT
6500 PRINT "LEAST SQUARES ESTIMATE OF WEIBULL PARAMETERS":PRINT:PRINT
6600 PRINT "SLOPE (BTA)","CHAR LIFE","B-10 LIFE","B-50 LIFE","CORR COEFF"
6700 PRINT B2,L,B3,B4,R1
6800 PRINT:PRINT:PRINT
6850 LPRINT"LEAST SQUARES ESTIMATE OF WEIBULL PARAMETERS":LPRINT
6855 LPRINT"SLOPE (BTA)","CHAR LIFE","B-10 LIFE","B-50 LIFE","CORR COEF"
6860 LPRINT B2,L,B3,B4,R1
6865 LPRINT:LPRINT:LPRINT:LPRINT
6900 PRINT "PRESS ENTER KEY TO CONTINUE";
7000 INPUT R$
7100 CLS
7200 PRINT "INSTANTANEOUS FAILURE RATES VS AGE"
7300 PRINT:PRINT
7400 PRINT " AGE"," INST F/R"
7450 LPRINT"INSTANTANEOUS FAILURE RATE VS AGE"
7455 LPRINT
7460 LPRINT" AGE"," INST F/R"
7500 FOR S=1 TO 3
7600 FOR J0=2 TO 10 STEP 2
7700 T=J0*10^S
7800 I=T^(B2-1)*B2/L^B2
```

```
7900 PRINT T,I
7950 LPRINT T,I
8000 NEXT J0
8100 NEXT S
8150 CLOSE
8155 LPRINT:LPRINT:LPRINT:LPRINT
8160 PRINT:PRINT:PRINT"IF YOU WOULD LIKE A PLOT OF THE WEIBULL, EXIT THIS PROGRA
M BY TYPING <N> -"
8165 PRINT:PRINT"RETURN TO DOS <SYSTEM> -"
8170 PRINT:PRINT"AND TYPE IN <WEIBULL.BAT>"
8200 PRINT:PRINT:PRINT:PRINT:PRINT:PRINT"DO YOU HAVE ANOTHER ANALYSIS TO RUN - (
Y) OR (N) ";:INPUT A$
8201 CLS
8202 IF A$="N" THEN CHAIN "WEIBER"
8203 IF A$="Y" THEN 1000
8205 CLS:GOTO 8200
8210 CHAIN "WEIBER"
8800 DATA 10,10
8910 DATA 85,1,135,2,150,3,150,4,190,5,200,6,200,7,240,8,240,9,250,10
9999 CLS:PRINT"SAVING SUSWEIBL ON DISK B":SAVE "B:SUSWEIBL":END
```

```
1   CLS
2   CLS
4   PRINT"                      PRESENT RISK ANALYSIS"
5   PRINT"                    WRITTEN BY JAMES L. BYERS"
6   PRINT"               NAVAL AIR DEVELOPMENT CENTER, CODE 6052"
7   PRINT"                      WARMINSTER, PA  18974"

9   PRINT"                          26 FEB 86"
10  REM
11  PRINT
12  REM ****************************** PROGRAM 'PRESRISK' ********************
15  PRINT"DATA INPUT ---------------- ENTER THE FOLLOWING :"
20  PRINT"4000 DATA B,H":PRINT
25  PRINT"          WHERE B = THE WEIBULL SLOPE 'BETA'"
30  PRINT"          AND   H = THE CHARACTERISTIC LIFE 'ETA'"
35  PRINT"4040 DATA N1,T1,N2,T2,...,etc.":PRINT
40  PRINT"          WHERE N1 IS THE NUMBER OF UNITS AT TIME T1"
45  PRINT"                T1 IS THE OPERATING TIME OF UNITS N1"
50  PRINT"                N2 IS THE NUMBER OF UNITS AT TIME T2"
55  PRINT"                T2 IS THE OPERATING TIME OF UNITS N2, etc.":PRINT
60  PRINT"USE ADDITIONAL LINE AS NEEDED TO ADD MORE DATA."
65  PRINT"WHEN THE LAST DATA IS ENTERED, INPUT <RUN 75> TO CONTINUE."
70  STOP
75  CLS
76  DIM N(25), T(25), F(25), NF(25), A(25)
80  PRINT"INPUT THE NUMBER OF DATA PAIRS JUST ENTERED";
85  INPUT N:PRINT:PRINT
86  PRINT"INPUT THE ENGINE AND/OR COMPONENT NAME";
87  INPUT E$
90  READ BTA,ETA
95  FOR I=1 TO N
100 READ N(I),T(I)
105 NEXT I
250 SUM=0
300 FOR I=1 TO N
350 F(I)=1-EXP(-1*(T(I)/ETA)^BTA)
400 NF(I)=F(I)*N(I)
450 SUM=SUM+NF(I)
500 NEXT I
501 CLS
505 PRINT"                   PRESENT RISK ANALYSIS":PRINT
506 PRINT"                 NUMBER OF FAILURES EXPECTED"
507 PRINT"               TO HAVE OCCURRED BASED ON CURRENT"
509 PRINT"                      OPERATING TIMES"
510 PRINT:PRINT"                         ";E$
512 PRINT:PRINT:PRINT
520 LPRINT"                  PRESENT RISK ANALYSIS":LPRINT
521 LPRINT"                NUMBER OF FAILURES EXPECTED"
522 LPRINT"              TO HAVE OCCURRED BASED ON CURRENT"
524 LPRINT"                     OPERATING TIMES"
525 LPRINT"                 WRITTEN BY J. L. BYERS":LPRINT"
```

```
526 LPRINT:LPRINT:LPRINT
528  LPRINT"DATA PAIRS USED:         (NO. OF UNITS, OPERATING TIME)":LPRINT
529   PRINT"DATA PAIRS USED:         (NO. OF UNITS, OPERATING TIME)":PRINT
530  FOR I=1 TO N
531   PRINT N(I);",";T(I);",";
532  LPRINT N(I);",";T(I);",";
533  NEXT I
534  PRINT:PRINT:LPRINT:LPRINT
550  LPRINT"NO. UNITS","TIME","   ";"% FAIL","        NO. FAILS":LPRINT
551   PRINT"NO. UNITS","TIME","   ";"% FAIL","        NO. FAILS":PRINT
600  FOR I=1 TO N
605  A(I)=F(I)/N(I)
650   PRINT "     ";N(I),T(I),F(I),"     ";A(I)
651  LPRINT "     ";N(I),T(I),F(I),"     ";A(I)
700  NEXT I
750   PRINT:PRINT:PRINT"TOTAL FAILURES = ";SUM:PRINT
751  LPRINT:LPRINT:LPRINT"TOTAL FAILURES = ";SUM:LPRINT
755   PRINT"VALUE OF WEIBULL SLOPE BETA IS";BTA:PRINT
756  LPRINT"VALUE OF WEIBULL SLOPE BETA IS";BTA:LPRINT
757   PRINT"VALUE OF CHARACTERISTIC LIFE ETA IS";ETA:PRINT
758  LPRINT"VALUE OF CHARACTERISTIC LIFE ETA IS";ETA:LPRINT
800 CLOSE
4000 DATA 1.655057,877.3896
4040 DATA 1,20,1,25,1,104,1,153,1,192,1,198,1,200,1,259,1,278,1,296,1,308,1,326,
1,341,1,410,1,437,1,501,1,580,1,594,1,623,1,668,1,677,1,811,1,862,1,904,1,1030
5000 PRINT"DO YOU HAVE ANOTHER ANALYSIS TO DO (Y) OR (N)";
5010 INPUT A$
5011 IF A$="Y" THEN 2
5012 IF A$="N" THEN 5050
5020 CLS:GOTO 5000
5050 CHAIN "WEIBER"
9998 END
9999 CLS:PRINT"SAVING PRESRISK ON DISK B":SAVE "B:PRESRISK":END
```

```
2    CLS
10   PRINT"                    FUTURE RISK ANALYSIS"
20   PRINT"                 WRITTEN BY JAMES L. BYERS"
30   PRINT"           NAVAL AIR DEVELOPMENT CENTER, CODE 6052"
35   PRINT"                    WARMINSTER, PA 18974"
40   PRINT"                       1 APRIL 1986"
50   REM
60   REM
70   REM ************************ PROGRAM FUTRISKS **************************
80   REM
90   REM
100  PRINT"DATA INPUT -------------------- ENTER THE FOLLOWING :"
110  PRINT"4000 DATA B,H"
120  PRINT"         WHERE B = THE WEIBULL SLOPE 'BETA'"
130  PRINT"               H = THE CHARACTERISTIC LIFE 'ETA'":PRINT
140  PRINT"4040 DATA MOS,UTR"
150  PRINT"         WHERE MOS IS THE NUMBER OF MONTHS INTO THE FUTURE"
160  PRINT"               UTR IS THE MONTHLY UTILIZATION RATE":PRINT
170  PRINT"4049 DATA N1,T1,N2,T2,...,etc."
180  PRINT"         WHERE N1 IS THE NUMBER OF UNITS AT TIME T1"
190  PRINT"               T1 IS THE OPERATING TIME OF UNITS N1"
200  PRINT"               N2 IS THE NUMBER OF UNITS AT TIME T2"
210  PRINT"               T2 IS THE OPERATING TIME OF UNITS N2, etc."
220  PRINT"USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA."
230  PRINT"WHEN THE LAST DATA PAIR IS ENTERED, INPUT <RUN 250> TO CONTINUE.";:ST
OP
240  STOP
250  CLS
260  PRINT"INPUT THE NUMBER OF DATA PAIRS JUST ENTERED.";
270  INPUT N:PRINT:PRINT
272  PRINT"INPUT THE ENGINE AND/OR COMPONENT NAME";
273  INPUT E$
280  DIM NF(41)
290  DIM N(41)
300  DIM T(41)
310  DIM G(41)
320  DIM K(41)
330  DIM R(41)
335  DIM F(41)
340  READ BETA,ETA
350  READ MOS,UTR
360  FOR I=1 TO N
370  READ N(I),T(I)
380  NEXT I
390  SUM=0
410  FOR I=1 TO N
420  F(I)=1-EXP(-1*(T(I)/ETA)^BETA)
430  NEXT I
440  RESTORE
450  READ BETA,ETA
460  READ MOS,UTR
470  FOR I=1 TO N
480  READ N(I),T(I)
490  NEXT I
```

```
500 M=MOS*UTR
510 FOR I=1 TO N
520 G(I)=T(I)+M
530 K(I)=1-EXP(-1*(G(I)/ETA)^BETA)
540 R(I)=(K(I)-F(I))/(1-F(I))
550 NF(I)=R(I)*N(I)
560 SUM=SUM+NF(I)
570 NEXT I
580 CLS
581 LPRINT"                    FUTURE RISK ANALYSIS"
582 LPRINT"           FORECASTED FAILURES OVER THE NEXT";MOS;"MONTHS TIME"
583 LPRINT"               UTILIZATION RATE IS";UTR;"HOURS PER MONTH"
584 LPRINT"                     WRITTEN BY JAMES L. BYERS":LPRINT"
             NADC, WARMINSTER, PA  18974":LPRINT"

E$:LPRINT
585  PRINT"                    FUTURE RISK ANALYSIS"
586  PRINT"           FORECASTED FAILURES OVER THE NEXT";MOS;"MONTHS TIME"
587  PRINT"               UTILIZATION RATE IS";UTR;"HOURS PER MONTH"
588 PRINT:PRINT:PRINT
590  PRINT"NO.UNITS","TIME","% FAIL","NO.FAILS","CUM FAILS"
595 LPRINT"NO.UNITS","TIME","% FAIL","NO.FAILS","CUM FAILS"
600 FOR I=1 TO N
605 CUMFAILS=CUMFAILS+NF(I)
610  PRINT USING "####         ";N(I),G(I);:PRINT USING "###.#####      ";R(I),
NF(I),CUMFAILS
615 LPRINT USING "####         ";N(I),G(I);:LPRINT USING "###.#####      ";R(I)
,NF(I),CUMFAILS
620 NEXT I
630 PRINT:PRINT"TOTAL FAILURES =";SUM
635 LPRINT:LPRINT"TOTAL FAILURES =";SUM
800 CLOSE
4000 DATA 6.557812,2741.127
4040 DATA 12,80
4049 DATA 54,400,81,500,54,600,162,700,54,800,189,900,270,1000,216,1100,270,1200
,243,1300,189,1400,135,1500,81,1600,54,1700
8000 PRINT:PRINT:PRINT"DO YOU HAVE ANOTHER ANALYSIS TO DO - (Y) OR (N)";:INPUT A
$
8010 IF A$="Y" THEN 2
8015 IF A$="N" THEN CHAIN "WEIBER"
8020 CLS:GOTO 8000
9998 END
9999 CLS:PRINT"SAVING FUTRISKS ON DISK B":SAVE "B:FUTRISKS":END
```

```
10 REM
20 REM
30 REM $$$$$$$$$$$$$$$$$$$ PROGRAM WEIBRSK1 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
40 REM
50 REM
60 REM
70 CLS
80 PRINT"                              WEIBULL RISK"
90 PRINT"                         A MONTE CARLO SIMULATION"
95 PRINT"                    WRITTEN BY JAMES L. BYERS - CODE 6052"
96 PRINT"            NAVAL AIR DEVELOPMENT CENTER, WARMINSTER, PA 18974"

100 PRINT:PRINT:PRINT
200 PRINT"    THIS PROGRAM PROVIDES THE CAPABILITY TO CALCULATE THE NUMBER OF FA
ILURES"
300 PRINT"FOR SEVERAL DIFFERENT PARTS IN AN ENGINE OVER A USER SPECIFIED TIME PE
RIOD."
400 PRINT"UP TO 25 ENGINES CAN BE ANALYSED WITH SCHEDULED INSPECTIONS WHERE THE
PARTS"
500 PRINT"CONSIDERED ARE BROUGHT TO ZERO-TIME, i.e., ARE MADE GOOD-AS-NEW."
550 PRINT
600 PRINT"    INPUTS CONSIST OF: NUMBER OF ENGINES; TIME SINCE LAST INSPECTION;
ANALYTICAL"
700 PRINT"TIME PERIOD; FLIGHT HOUR UTILIZATION RATE; TIME BETWEEN INSPECTIONS, I
NITIAL"
800 PRINT"TIME ON ENGINES; WEIBULL PARAMETERS (BETA & ETA); and ENGINE DESIGNATI
ON."
850 PRINT
900 PRINT"    OUTPUT CONSISTS OF: TOTAL ENGINE FLIGHT HOURS; CUMULATIVE FLIGHT H
OURS;"
1000 PRINT"TIME TO FAIL FOR EACH MODE; and TOTAL NUMBER OF FAILURES BY ITERATION
."
1050 PRINT
1100 PRINT"TO CONTINUE INPUT 1 AND <ENTER>.  TO QUIT INPUT -1 AND <ENTER>.";
1200 PRINT"  YOUR CHOICE";:INPUT Z1
1300 CLS
1400 IF Z1=1 THEN 17300
1500 IF Z1=-1 THEN 26100
1600 GOTO 1100
1700 STOP
1900 DIM ETA(6)
2000 DIM BETA(6)
2100 DIM N(25)
2200 DIM TT(25)
2300 DIM T(25)
2400 DIM BUST(6)
2500 DIM MTF(25)
2600 DIM F(25)
2700 DIM TF(55,6)
2800 DIM RUNFAIL(10)
2950 RANDOMIZE Z
3000 TOTFAIL=0
3100 FOR K=1 TO J
3200 READ BETA(K)
3300 NEXT K
3400 FOR K=1 TO J
3500 READ ETA(K)
3600 NEXT K
```

```
3700 FOR K=1 TO S
3800 READ N(K),T(K)
4100 NEXT K
4200 RESTORE
4300 SUM=0
4400 TMAX=UTR*MOI
4500 LPRINT"                              WEIBULL RISK ANALYSIS"
4600 LPRINT"                            A MONTE CARLO SIMULATION"
4700 LPRINT"                                   WEIBRSK1"
4725 LPRINT"                       WRITTEN BY: JAMES L. BYERS, CODE 6052"
4730 LPRINT"                           NAVAL AIR DEVELOPMENT CENTER"
4735 LPRINT"                              WARMINSTER, PA  18974"

LPRINT
4800 LPRINT"                                 ENGINE :";E$:LPRINT:LPRINT:LPRINT
4900 LPRINT"BETA VALUES :"
5000 FOR Y=1 TO J:LPRINT BETA(Y),:NEXT Y:LPRINT:LPRINT:LPRINT
5100 LPRINT"ETA VALUES :"
5200 FOR Y=1 TO J:LPRINT ETA(Y),:NEXT Y:LPRINT:LPRINT:LPRINT
5300 LPRINT"DATA PAIRS :"
5400 LPRINT"NO. ENGS.";"     INIT. TIME"
5500 FOR Y=1 TO S:LPRINT"   ";N(Y),T(Y):NEXT Y:LPRINT:LPRINT:LPRINT
5600 PRINT"MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS";TMAX;"HOURS"
:PRINT:LPRINT"MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS";TMAX;"HOU
RS":LPRINT
5700 PRINT"INSPECTION INTERVAL FOR THIS ANALYSIS IS";INSPT;"HOURS":PRINT:LPRINT"
INSPECTION INTERVAL FOR THIS ANALYSIS IS";INSPT;"HOURS":LPRINT
5800 PRINT"TIME DURATION OF THIS ANALYSIS IS";MOI;"MONTHS":LPRINT"TIME DURATION
OF THIS ANALYSIS IS";MOI;"MONTHS":LPRINT:PRINT
5900 PRINT"UTILIZATION RATE IS";UTR;"HOURS PER ENGINE PER MONTH":PRINT:LPRINT"UT
ILIZATION RATE IS";UTR;"HOURS PER ENGINE PER MONTH":LPRINT
6000 FOR L=1 TO S
6100 PRINT" ********************* DATA PAIR NUMBER";L;" ************************
**":PRINT:PRINT
6200 LPRINT" ********************* DATA PAIR NUMBER";L;" ***********************
***":LPRINT:LPRINT
6300 FOR M=1 TO X
6400 PRINT"                      * * * ITERATION NUMBER";M;"* * *":PRINT:PRINT
6500 LPRINT"                      * * * ITERATION NUMBER";M;"* * *":LPRINT:LPRIN
T
6600 FOR I=1 TO N(L)
6700 PRINT"                              ENGINE NUMBER";I:PRINT
6800 LPRINT"                              ENGINE NUMBER";I:PRINT
7000 FOR K=1 TO J
7100 TF(I,K)=ETA(K)*(LOG(1/(1-RND(Z))))^(1/(BETA(K)))
7200 IF TF(I,K)<T(L) THEN 7100
7300 IF TF(I,K)<INSPT THEN 7500
7400 IF TF(I,K)>INSPT THEN 7800
7500 Q(K)=1:BUST(K)=BUST(K)+Q(K):Q(K)=0
7800 NEXT K
7830 FOR K=1 TO J:LPRINT TF(I,K),:NEXT K:LPRINT
7835 FOR K=1 TO J: PRINT TF(I,K),:NEXT K: PRINT
7900 GOSUB 10000
8000 GOTO 13500
```

```
9000 SUM=SUM+FAILS
9100 TOTFAIL=TOTFAIL+SUM
9200 RUNFAILS=RUNFAILS+SUM
9300 FAIL(I)=FAIL(I)+FAILS
9400 PRINT"CUMULATIVE FAILURES FOR THIS DATA PAIR ARE";TOTFAIL
9500 LPRINT"CUMULATIVE FAILURES FOR THIS DATA PAIR ARE";TOTFAIL
9600 FAILS=0
9700 SUM=0
9800  PRINT"NUMBER OF FAILURES FOR ENGINE";I;"="FAIL(I): PRINT
9900 LPRINT"NUMBER OF FAILURES FOR ENGINE";I;"="FAIL(I):LPRINT
9910 BIGF(I)=BIGF(I)+FAIL(I):FAIL(I)=0:TT(I)=0
9920 GOTO 15000
10000 FOR A=1 TO J-1
10100 B=A
10200 FOR C=A+1 TO J
10300 IF TF(I,C)<TF(I,B) THEN 10500
10400 GOTO 10600
10500 B=C
10600 NEXT C
10700 D=TF(I,A)
10800 TF(I,A)=TF(I,B)
10900 TF(I,B)=D
11000 NEXT A
11100 RETURN
12000 FOR K=1 TO J
12100 TF(I,K)=ETA(K)*(LOG(1/(1-RND(Z))))^(1/(BETA(K)))
12400 IF TF(I,K)<INSPT THEN 12500 ELSE 12600
12500 Q(K)=1:BUST(K)=BUST(K)+Q(K):Q(K)=0
12600 NEXT K
12605 FOR K=1 TO J:LPRINT TF(I,K),:NEXT K:LPRINT
12606 FOR K=1 TO J: PRINT TF(I,K),:NEXT K: PRINT
12610 GOSUB 10000
13500 IF TF(I,1)<INSPT AND (TF(I,1)+TT(I))<TMAX THEN FAILS=FAILS+1
13600 IF TF(I,1)>INSPT THEN TF(I,1)=INSPT
13700 TT(I)=TT(I)+TF(I,1)
13800 IF TT(I)=>TMAX THEN TT(I)=TMAX
14000 LPRINT"TIME ON ENGINE IS";TT(I)
14100 IF TT(I)=>TMAX THEN 9000 ELSE 12000
15000 NEXT I
15100 PRINT:LPRINT:LPRINT"TOTAL FAILURES ITERATION NUMBER";M;"=";RUNFAILS
15200 PRINT"TOTAL FAILURES ITERATION NUMBER";M;"=";RUNFAILS:PRINT:PRINT:RUNFAIL(
M)=RUNFAILS
15300 SUM=0:FAILS=0:RUNFAILS=0
15400 NEXT M
15500 PRINT:PRINT
15600 LPRINT:LPRINT
15700 SUM=TOTFAIL/X:LPRINT:LPRINT"AVERAGE NUMBER FAILURES";X;"ITERATIONS = ";SUM
:LPRINT:LPRINT
15800 PRINT"AVERAGE NUMBER FAILURES";X;"ITERARIONS = ";SUM:PRINT
15900 TOTFAIL=0:SUM=0
16000 FOR M=1 TO X
16100 PRINT"NUMBER OF FAILURES IN ITERATION";M;"=";RUNFAIL(M);:PRINT
16200 NEXT M
```

```
16300 FOR R=1 TO N(L):BIGF(R)=BIGF(R)/I:NEXT R
16400 FOR R=1 TO N(L):PRINT"AVERAGE NUMBER OF FAILURES FOR ENGINE";R;"IS";BIGF(R
):NEXT R:PRINT
16500 FOR M=1 TO I:LPRINT"NUMBER OF FAILURES IN ITERATION";M;"=";RUNFAIL(M):LPRI
NT:NEXT M
16600 FOR R=1 TO N(L):LPRINT"AVERAGE NUMBER OF FAILURES FOR ENGINE";R;"IS";BIGF(
R):NEXT R:LPRINT:FOR R=1 TO N(L):BIGF(R)=0:NEXT R
16800 NEXT L
16900 GOTO 28500
17000 REM
17100 REM ################## DATA INPUT SECTION ##############################
17200 REM
17300 CLS:PRINT"THIS IS THE DATA INPUT SECTION OF THE WEIBULL RISK CODE."
17400 PRINT
17500 PRINT"YOU WILL BE ASKED TO INPUT VARIOUS DATA IN A GIVEN FORMAT."
17600 PRINT
17700 PRINT"THE FORMAT IS CRITICAL SO FOLLOW INSTRUCTIONS CAREFULLY.":PRINT
17800 PRINT"TYPE 1 <ENTER> TO INPUT DATA.  TYPE -1 <ENTER> TO QUIT."
17900 INPUT Z1
18000 CLS
18100 IF Z1=-1 THEN 26100
18200 IF Z1=1 THEN 20200 ELSE 17800
20200 CLS
20300 PRINT"NOW TYPE THE FOLLOWING :":PRINT
20400 PRINT"25800 DATA BETA(1),BETA(2),...,BETA(J)"
20500 PRINT"          WHERE BETA(1) IS THE WEIBULL SLOPE FOR THE FIRST MODE OF"
20600 PRINT"          FAILURE, BETA(2) IS THE WEIBULL SLOPE FOR THE SECOND MODE"
20700 PRINT"          OF FAILURE, AND SO ON UNTIL THE NUMBER OF BETA'S CORRESPON
D"
20800 PRINT"          TO THE INTEGER FOR THE NUMBER OF FAILURE MODES.  SEPARATE"
20900 PRINT"          BETA'S WITH COMMA'S.":PRINT
21000 PRINT"AFTER THE LAST BETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 21300' AN
D"
21100 PRINT"<ENTER>."
21200 STOP
21300 CLS
21400 PRINT"NOW TYPE THE FOLLOWING :":PRINT
21500 PRINT"25900 DATA ETA(1),ETA(2),...,ETA(J)"
21600 PRINT"          WHERE ETA(1) IS THE CHARACTERISTIC LIFE FOR THE FIRST MODE
"
21700 PRINT"          OF FAILURE, ETA(2) IS THE CHARACTERISTIC LIFE FOR THE"
21800 PRINT"          SECOND MODE OF FAILURE, AND SO ON UNTIL THE NUMBER OF ETA'
S"
21900 PRINT"          CORRESPOND TO THE INTEGER FOR THE NUMBER OF FAILURE MODES.
"
22000 PRINT"          SEPARATE ETA'S WITH COMMA'S.":PRINT
22100 PRINT"AFTER THE LAST ETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 22400' AND
"
22200 PRINT"<ENTER>."
22300 STOP
22400 CLS
```

```
22500 PRINT"NOW TYPE THE FOLLOWING :":PRINT
22600 PRINT"26000 DATA N1,T1,N2,T2,...,etc."
22700 PRINT"          WHERE N1 IS THE NUMBER OF ENGINES AT TIME T1"
22800 PRINT"                T1 IS THE OPERATING TIME OF ENGINES N1"
22900 PRINT"                N2 IS THE NUMBER OF ENGINES AT TIME T2"
23000 PRINT"                T2 IS THE OPERATING TIME OF ENGINES N2, etc.":PRINT
23100 PRINT"USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA."
23200 PRINT"WHEN THE LAST DATA PAIR IS ENTERED, TYPE 'RUN 23400' AND <ENTER>."
23300 STOP
23400 CLS
23500 PRINT"NOW INPUT THE NUMBER OF DATA PAIRS JUST ENTERED.";:INPUT S:PRINT
23700 PRINT"INPUT THE TOTAL NUMBER OF ENGINES IN THE SAMPLE - NOT OVER 25.";:INP
UT R:PRINT
23900 PRINT"INPUT THE NUMBER OF MONTHS THAT THIS ANALYSIS WILL COVER, i.e., 36 F
OR THREE    YEARS.";:INPUT MOI:PRINT
24200 PRINT"NEXT, INPUT THE OPERATING HOURS PER MONTH (AVERAGE) OVER THE TIME"
24300 PRINT"PERIOD OF THIS ANALYSIS.";:INPUT UTR:PRINT
24500 PRINT"INPUT THE INSPECTION INTERVAL FOR THE ENGINE OF THIS ANALYSIS.";:INP
UT INSPT:PRINT
24700 PRINT"INPUT THE NUMBER OF FAILURE MODES OF THIS ANALYSIS.";:INPUT J:PRINT
24900 PRINT"INPUT THE ENGINE DESIGNATION.";:INPUT E$:PRINT
24950 PRINT"INPUT ANY NUMBER BETWEEN +1 AND +32767 TO SEED THE RANDOM NUMBER GEN
ERATOR.    USE A DIFFERENT NUMBER FOR EACH ANALYSIS.";:INPUT Z:PRINT
24960 PRINT"LASTLY, INPUT THE NUMBER OF ITERATIONS TO BE PERFORMED DURING THE AN
ALYSIS.";:INPUT X
25100 CLS
25200 REM
25400 REM $$$$$$$$$$$$$$$$$$$ END OF DATA INPUT SECTION $$$$$$$$$$$$$$$$$$$$$$$
25500 GOTO 1900
25600 REM
25800 DATA 3.55
25900 DATA 2741
26000 DATA 5,1000
26100 END
26200 REM
26300 CLOSE
28500 PRINT:PRINT:PRINT"DO YOU HAVE OTHER ANALYSES TO DO - (Y) OR (N)";:INPUT A$
28510 IF A$="Y" THEN 17300
28520 IF A$="N" THEN CHAIN "WEIBER"
28550 CLS:GOTO 28500
29990 END
30000 CLS:PRINT:PRINT:PRINT"SAVING WEIBRSK1 ON DISK B":SAVE "B:WEIBRSK1":END
```

```
10 REM
20 REM
30 REM ******************** PROGRAM SHTWEIB2 *********************************
40 REM
50 REM
60 REM
70 CLS
80 PRINT"                              WEIBULL RISK"
85 PRINT"                                'SHORT'"
90 PRINT"                         A MONTE CARLO SIMULATION"
95 PRINT"                  WRITTEN BY JAMES L. BYERS - CODE 6052"
96 PRINT"            NAVAL AIR DEVELOPMENT CENTER, WARMINSTER, PA 18974"

100 PRINT:PRINT:PRINT
200 PRINT"    THIS PROGRAM PROVIDES THE CAPABILITY TO CALCULATE THE NUMBER OF FA
ILURES"
300 PRINT"FOR SEVERAL DIFFERENT PARTS IN AN ENGINE OVER A USER SPECIFIED TIME PE
RIOD."
400 PRINT"UP TO 250 ENGINES CAN BE ANALYSED WITH SCHEDULED INSPECTIONS WHERE THE
 PARTS"
500 PRINT"CONSIDERED ARE BROUGHT TO ZERO-TIME, i.e., ARE MADE GOOD-AS-NEW."
550 PRINT
600 PRINT"    INPUTS CONSIST OF: NUMBER OF ENGINES; TIME SINCE LAST INSPECTION;
ANALYTICAL"
700 PRINT"TIME PERIOD; FLIGHT HOUR UTILIZATION RATE; TIME BETWEEN INSPECTIONS, I
NITIAL"
800 PRINT"TIME ON ENGINES; WEIBULL PARAMETERS (BETA & ETA); and ENGINE DESIGNATI
ON."
850 PRINT
900 PRINT"    OUTPUT CONSISTS OF TOTAL NUMBER OF FAILURES BY ITERATION AND AVERA
GES"
1000 PRINT"PER ENGINE AND ITERATION."
1050 PRINT
1100 PRINT"TO CONTINUE INPUT 1 AND <ENTER>.  TO QUIT INPUT -1 AND <ENTER>.";
1200 PRINT"  YOUR CHOICE";:INPUT Z1
1300 CLS
1400 IF Z1=1 THEN 17300
1500 IF Z1=-1 THEN 26100
1600 GOTO 1100
1700 STOP
1900 DIM ETA(10)
2000 DIM BETA(10)
2050 DIM FAIL(250)
2055 DIM BIGF(250)
2100 DIM N(250)
2200 DIM TT(250)
2300 DIM T(250)
2400 DIM BUST(50)
2500 DIM MTF(250)
2600 DIM F(250)
2700 DIM TF(250,10)
2800 DIM RUNFAIL(X)
2950 RANDOMIZE Z
3000 TOTFAIL=0
```

```
3100 FOR K=1 TO J
3200 READ BETA(K)
3300 NEXT K
3400 FOR K=1 TO J
3500 READ ETA(K)
3600 NEXT K
3700 FOR K=1 TO S
3800 READ N(K),T(K)
4100 NEXT K
4200 RESTORE
4300 SUM=0
4400 TMAX=UTR*MOI
4450 LPRINT:LPRINT:LPRINT
4500 LPRINT"                         WEIBULL RISK ANALYSIS"
4600 LPRINT"                       A MONTE CARLO SIMULATION"
4700 LPRINT"                               SHTWEIB2"
4725 LPRINT"                 WRITTEN BY: JAMES L. BYERS, CODE 6052"
4730 LPRINT"                     NAVAL AIR DEVELOPMENT CENTER"
4735 LPRINT"                        WARMINSTER, PA  18974"

PRINT
4800 LPRINT"                              ENGINE :";E$:LPRINT:LPRINT:LPRINT
4900 LPRINT"BETA VALUES :"
5000 FOR Y=1 TO J:LPRINT BETA(Y),:NEXT Y:LPRINT:LPRINT:LPRINT
5100 LPRINT"ETA VALUES :"
5200 FOR Y=1 TO J:LPRINT ETA(Y),:NEXT Y:LPRINT:LPRINT:LPRINT
5300 LPRINT"DATA PAIRS :"
5400 LPRINT"NO. ENGS.";"     INIT. TIME"
5500 FOR Y=1 TO S:LPRINT"   ";N(Y),T(Y):NEXT Y:LPRINT:LPRINT:LPRINT
5600 PRINT"MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS";TMAX;"HOURS"
:PRINT:LPRINT"MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS";TMAX;"HOU
RS":LPRINT
5700 PRINT"INSPECTION INTERVAL FOR THIS ANALYSIS IS";INSPT;"HOURS":PRINT:LPRINT"
INSPECTION INTERVAL FOR THIS ANALYSIS IS";INSPT;"HOURS":LPRINT
5800 PRINT"TIME DURATION OF THIS ANALYSIS IS";MOI;"MONTHS":LPRINT"TIME DURATION
OF THIS ANALYSIS IS";MOI;"MONTHS":LPRINT:PRINT
5900 PRINT"UTILIZATION RATE IS";UTR;"HOURS PER ENGINE PER MONTH":PRINT:LPRINT"UT
ILIZATION RATE IS";UTR;"HOURS PER ENGINE PER MONTH":LPRINT
6000 FOR L=1 TO S
6100 PRINT" ********************** DATA PAIR NUMBER";L;" *************************
**":PRINT:PRINT
6200 LPRINT" ********************** DATA PAIR NUMBER";L;" ************************
***":LPRINT:LPRINT
6250 PRINT:PRINT:PRINT:PRINT"                 PLEASE BE PATIENT ------ I'M COMPUT
ING THE FAILURES"
6300 FOR M=1 TO X
6600 FOR I=1 TO N(L)
7000 FOR K=1 TO J
7100 TF(I,K)=ETA(K)*(LOG(1/(1-RND(Z))))^(1/(BETA(K)))
7200 IF TF(I,K)<T(L) THEN 7100
7300 IF TF(I,K)<INSPT THEN 7500
7400 IF TF(I,K)>INSPT THEN 7800
7500 Q(K)=1:BUST(K)=BUST(K)+Q(K):Q(K)=0
7800 NEXT K
7900 GOSUB 10000
8000 GOTO 13500
9000 SUM=SUM+FAILS
9100 TOTFAIL=TOTFAIL+SUM
```

```
9150 PRINT TOTFAIL,
9200 RUNFAILS=RUNFAILS+SUM
9300 FAIL(I)=FAIL(I)+FAILS
9600 FAILS=0
9700 SUM=0
9910 BIGF(I)=BIGF(I)+FAIL(I):FAIL(I)=0:TT(I)=0
9920 GOTO 15000
10000 FOR A=1 TO J-1
10100 B=A
10200 FOR C=A+1 TO J
10300 IF TF(I,C)<TF(I,B) THEN 10500
10400 GOTO 10600
10500 B=C
10600 NEXT C
10700 D=TF(I,A)
10800 TF(I,A)=TF(I,B)
10900 TF(I,B)=D
11000 NEXT A
11100 RETURN
12000 FOR K=1 TO J
12100 TF(I,K)=ETA(K)*(LOG(1/(1-RND(Z))))^(1/(BETA(K)))
12400 IF TF(I,K)<INSPT THEN 12500 ELSE 12600
12500 Q(K)=1:BUST(K)=BUST(K)+Q(K):Q(K)=0
12600 NEXT K
12610 GOSUB 10000
13500 IF TF(I,1)<INSPT AND (TF(I,1)+TT(I))<TMAX THEN FAILS=FAILS+1
13600 IF TF(I,1)>INSPT THEN TF(I,1)=INSPT
13700 TT(I)=TT(I)+TF(I,1)
13800 IF TT(I)=>TMAX THEN TT(I)=TMAX
14100 IF TT(I)=>TMAX THEN 9000 ELSE 12000
15000 NEXT I
15200 RUNFAIL(M)=RUNFAILS
15300 SUM=0:FAILS=0:RUNFAILS=0
15400 NEXT M
15500 PRINT:PRINT
15600 LPRINT:LPRINT
15650 CLS
15700 SUM=TOTFAIL/X:LPRINT:LPRINT"AVERAGE NUMBER FAILURES";X;"ITERATIONS = ";SUM
:LPRINT:LPRINT
15800 PRINT"AVERAGE NUMBER FAILURES";X;"ITERAIONS = ";SUM:PRINT
15900 TOTFAIL=0:SUM=0
16000 FOR M=1 TO X
16100 PRINT"NUMBER OF FAILURES IN ITERATION";M;"=";RUNFAIL(M);:PRINT
16200 NEXT M
16300 FOR R=1 TO N(L):BIGF(R)=BIGF(R)/X:NEXT R
16400 FOR R=1 TO N(L):PRINT"AVERAGE NUMBER OF FAILURES FOR ENGINE";R;"IS";BIGF(R
):NEXT R:PRINT
16500 FOR M=1 TO X:LPRINT"NUMBER OF FAILURES IN ITERATION";M;"=";RUNFAIL(M):LPRI
NT:NEXT M
16600 FOR R=1 TO N(L):LPRINT"AVERAGE NUMBER OF FAILURES FOR ENGINE";R;"IS";BIGF(
R):NEXT R:LPRINT:FOR R=1 TO N(L):BIGF(R)=0:NEXT R
16800 NEXT L
16900 GOTO 20500
17000 REM
```

```
17100 REM ################### DATA INPUT SECTION ##############################
17200 REM
17300 CLS:PRINT"THIS IS THE DATA INPUT SECTION OF THE WEIBULL RISK CODE (SHORT V
ERSION)."
17400 PRINT
17500 PRINT"YOU WILL BE ASKED TO INPUT VARIOUS DATA IN A GIVEN FORMAT."
17600 PRINT
17700 PRINT"THE FORMAT IS CRITICAL SO FOLLOW INSTRUCTIONS CAREFULLY.":PRINT
17800 PRINT"TYPE 1 <ENTER> TO INPUT DATA.  TYPE -1 <ENTER> TO QUIT.  YOUR CHOICE
";
17900 INPUT Z1
18000 CLS
18100 IF Z1=-1 THEN 26100
18200 IF Z1=1 THEN 20200 ELSE 17800
20200 CLS
20300 PRINT"NOW TYPE THE FOLLOWING :":PRINT
20400 PRINT"25800 DATA BETA(1),BETA(2),...,BETA(J)"
20500 PRINT"          WHERE BETA(1) IS THE WEIBULL SLOPE FOR THE FIRST MODE OF"
20600 PRINT"          FAILURE, BETA(2) IS THE WEIBULL SLOPE FOR THE SECOND MODE"
20700 PRINT"          OF FAILURE, AND SO ON UNTIL THE NUMBER OF BETA'S CORRESPON
D"
20800 PRINT"          TO THE INTEGER FOR THE NUMBER OF FAILURE MODES.  SEPARATE"
20900 PRINT"          BETA'S WITH COMMA'S.":PRINT
21000 PRINT"AFTER THE LAST BETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 21300' AN
D"
21100 PRINT"<ENTER>."
21200 STOP
21300 CLS
21400 PRINT"NOW TYPE THE FOLLOWING :":PRINT
21500 PRINT"25900 DATA ETA(1),ETA(2),...,ETA(J)"
21600 PRINT"          WHERE ETA(1) IS THE CHARACTERISTIC LIFE FOR THE FIRST MODE
"

21700 PRINT"          OF FAILURE, ETA(2) IS THE CHARACTERISTIC LIFE FOR THE"
21800 PRINT"          SECOND MODE OF FAILURE, AND SO ON UNTIL THE NUMBER OF ETA'
S"
21900 PRINT"          CORRESPOND TO THE INTEGER FOR THE NUMBER OF FAILURE MODES.
"

22000 PRINT"          SEPARATE ETA'S WITH COMMA'S.":PRINT
22100 PRINT"AFTER THE LAST ETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 22400' AND
"

22200 PRINT"<ENTER>."
22300 STOP
22400 CLS
22500 PRINT"NOW TYPE THE FOLLOWING :":PRINT
22600 PRINT"26000 DATA N1,T1,N2,T2,...,etc."
22700 PRINT"          WHERE N1 IS THE NUMBER OF ENGINES AT TIME T1"
22800 PRINT"                T1 IS THE OPERATING TIME OF ENGINES N1"
22900 PRINT"                N2 IS THE NUMBER OF ENGINES AT TIME T2"
23000 PRINT"                T2 IS THE OPERATING TIME OF ENGINES N2, etc.":PRINT
23100 PRINT"USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA."
23200 PRINT"WHEN THE LAST DATA PAIR IS ENTERED, TYPE 'RUN 23400' AND <ENTER>."
23300 STOP
```

```
23400 CLS
23500 PRINT"NOW INPUT THE NUMBER OF DATA PAIRS JUST ENTERED.";:INPUT S:PRINT
23700 PRINT"INPUT THE TOTAL NUMBER OF ENGINES IN THE SAMPLE - NOT OVER 250.";:IN
PUT R:PRINT
23900 PRINT"INPUT THE NUMBER OF MONTHS THAT THIS ANALYSIS WILL COVER, i.e., 36 F
OR THREE    YEARS.";:INPUT MOI:PRINT
24200 PRINT"NEXT, INPUT THE OPERATING HOURS PER MONTH (AVERAGE) OVER THE TIME"
24300 PRINT"PERIOD OF THIS ANALYSIS.";:INPUT UTR:PRINT
24500 PRINT"INPUT THE INSPECTION INTERVAL FOR THE ENGINE OF THIS ANALYSIS.";:INP
UT INSPT:PRINT
24700 PRINT"INPUT THE NUMBER OF FAILURE MODES OF THIS ANALYSIS.";:INPUT J:PRINT
24900 PRINT"INPUT THE ENGINE DESIGNATION.";:INPUT E$:PRINT
24950 PRINT"INPUT ANY NUMBER BETWEEN +1 AND +32767 TO SEED THE RANDOM NUMBER GEN
ERATOR.    USE A DIFFERENT NUMBER FOR EACH ANALYSIS.";:INPUT Z:PRINT
24960 PRINT"LASTLY, INPUT THE NUMBER OF ITERATIONS TO BE PERFORMED DURING THE AN
ALYSIS.";:INPUT X
25100 CLS
25200 REM
25400 REM $$$$$$$$$$$$$$$$$$$$ END OF DATA INPUT SECTION $$$$$$$$$$$$$$$$$$$$$$$$
25500 GOTO 1900
25600 REM
25800 DATA 3.55
25900 DATA 2741
26000 DATA 5,1000
26100 END
26200 REM
26300 CLOSE
28500 PRINT:PRINT:PRINT"DO YOU HAVE OTHER ANALYSES TO DO - (Y) OR (N)";:INPUT A$
28510 IF A$="Y" THEN 17300
28520 IF A$="N" THEN CHAIN "WEIBER"
28550 CLS:GOTO 28500
29990 END
30000 CLS:PRINT:PRINT:PRINT"SAVING SHTWEIB2 ON DISK B":SAVE "B:SHTWEIB2":END
```

```
2 CLS
3 REM
4 REM
5 REM ************************ PROGRAM ETACALC **********************************
6 REM
7 REM
8 REM
9 REM
11 PRINT"                        PROGRAM ETACALC"
12 PRINT"               WRITTEN BY JAMES L. BYERS, CODE 6052"
13 PRINT"        NAVAL AIR DEVELOPMENT CENTER, WARMINSTER, PA 18974"

15 PRINT"DATA INPUT ------- INPUT DATA AS INSTRUCTED.":PRINT
20 PRINT"TYPE IN THE FOLLOWING DATA STATEMENT TO INPUT THE WEIBULL SLOPE 'BETA'
        AND THE TOTAL NUMBER OF FAILURES :"
25 PRINT"1700 DATA B,T"
30 PRINT"            WHERE 'B' IS BETA AND 'T' IS THE TOTAL NUMBER OF FAILURES.
                     IF THERE ARE NO FAILURES, INPUT 1 FOR T.":PRINT
35 PRINT"THEN TYPE IN THE FOLLOWING STATEMENT TO INPUT THE DATA PAIRS :"
40 PRINT"1800 DATA N1,T1,N2,T2,...,etc."
45 PRINT"            WHERE N1 IS THE NUMBER OF UNITS AT TIME T1, AND
                           T1 IS THE OPERATING TIME ON UNITS N1."
50 PRINT"                  N2 IS THE NUMBER OF UNITS AT TIME T2, AND
                           T2 IS THE OPERATING TIME ON UNITS N2, etc.":PRINT
55 PRINT"WHEN ALL DATA HAS BEEN ENTERED, TYPE 'RUN 100' AND <ENTER>."
60 STOP
65 CLS
100 CLS
200 DIM N(50),T(50),M(50)
300 PRINT"INPUT THE NUMBER OF DATA PAIRS JUST ENTERED";:INPUT R
400 CLS
500 READ B,T
600 SUM=0
610 PRINT"                 CALCULATION OF THE CHARACTERISTIC LIFE ETA"
620 PRINT"                BASED ON KNOWN FAILURES AND WEIBULL SLOPE BETA"
630 LPRINT"                 CALCULATION OF THE CHARACTERISTIC LIFE ETA"
649 LPRINT"                BASED ON KNOWN FAILURES AND WEIBULL SLOPE BETA"
655 LPRINT"                    WRITTEN BY: JAMES L. BYERS, CODE 6052"
660 LPRINT"                       NAVAL AIR DEVELOPMENT CENTER"
665 LPRINT"                          WARMINSTER, PA  18974"

680 PRINT:PRINT:LPRINT:LPRINT
700  PRINT"DATA PAIRS :              (NO. OF ENGS. AND TIME ON ENGS.)":PRINT
750 LPRINT"DATA PAIRS :              (NO. OF ENGS. AND TIME ON ENGS.)":PRINT
800 FOR I=1 TO R
900 READ N(I),T(I)
1000 PRINT N(I);",";T(I);",";
1050 LPRINT N(I);",";T(I);",";
1100 M(I)=((N(I))*(T(I))^(B))/T
1200 SUM=SUM+M(I)
1300 NEXT I
1400 E=(SUM)^(1/B)
1500 PRINT:PRINT:PRINT
1550 LPRINT:LPRINT:LPRINT
```

```
1600  PRINT"THE CALCULATED VALUE OF ETA IS";E:PRINT
1650 LPRINT"THE CALCULATED VALUE OF ETA IS";E:LPRINT
1660  PRINT"THE VALUE OF BETA USED IS";B:PRINT
1670 LPRINT"THE VALUE OF BETA USED IS";B:LPRINT
1700 DATA 3,531
1800 DATA 40,19138,48,41578,54,59636,44,78536,38,96564,22,111132,48,130206,94,14
5124,38,164920,38,183006,29,201298,39,220112
2000 CLOSE
8000 PRINT:PRINT:PRINT"DO YOU WISH TO CALCULATE ANOTHER VALUE - (Y) OR (N)";:INP
UT A$
8010 IF A$="Y" THEN 2
8020 IF A$="N" THEN CHAIN "WEIBER"
8050 CLS:GOTO 8000
9998 END
9999 CLS:PRINT"SAVING ETACALC ON DISK B":SAVE "B:ETACALC":END
```

```
100 CLS
200 REM
300 REM
400 REM
500 REM ************************ PROGRAM CNFINTBE *******************************
600 REM
700 REM
800 REM
900 PRINT"                    CONFIDENCE INTERVAL CALCULATION"
1000 PRINT"                                FOR"
1100 PRINT"                  BETA - ETA - TIME TO FIRST FAILURE"
1200 PRINT"                 WRITTEN BY JAMES L. BYERS, CODE 6052"
1300 PRINT"                     NAVAL AIR DEVELOPMENT CENTER"
1400 PRINT"                        WARMINSTER, PA 18974"

1500 LPRINT"                   CONFIDENCE INTERVAL CALCULATION"
1600 LPRINT"                               FOR"
1700 LPRINT"                 BETA - ETA - TIME TO FIRST FAILURE"
1800 LPRINT"                WRITTEN BY JAMES L. BYERS, CODE 6052"
1900 LPRINT"                    NAVAL AIR DEVELOPMENT CENTER"
2000 LPRINT"                       WARMINSTER,PA 18974"

NT:LPRINT
2050 LPRINT"*********************************************************************":L
PRINT:LPRINT
2100 REM
2200 REM
2300 REM
2400 PRINT:PRINT:PRINT:PRINT"WHICH CONFIDENCE LEVEL (0.99, 0.95, OR 0.90) DO YOU
 WISH TO USE TO              ESTABLISH A CONFIDENCE INTERVAL AROUND BETA AND ETA
";:INPUT A1:PRINT:PRINT
2500 PRINT"WHAT IS THE ESTIMATED VALUE OF BETA";:INPUT BH:PRINT:PRINT
2600 PRINT"WHAT IS THE ESTIMATED VALUE OF ETA";:INPUT EH:PRINT:PRINT
2700 PRINT"WHAT NUMBER OF FAILURES ARE THESE VALUES OF BETA AND ETA BASED ON";:I
NPUT N1:PRINT:PRINT
2800 IF A1=.99 THEN Z=2.576
2900 IF A1=.95 THEN Z=1.96
3000 IF A1=.9 THEN Z=1.645
3100 EP1B=(-.78*Z)/(N1^(1/2))
3200 EP2B=-EP1B
3300 EP1E=(-1.05*Z)/(N1^(1/2))
3400 EP2E=-EP1E
3500 LIMITB1=BH*EXP(EP1B)
3600 LIMITB2=BH*EXP(EP2B)
3700 LIMITE1=EH*EXP(EP1E/BH)
3800 LIMITE2=EH*EXP(EP2E/BH)
3900 PRINT"THE CONFIDENCE INTERVALS, OR MEASUREMENT OF THE PRECISION OF THE"
4000 PRINT"ESTIMATION OF BETA AND ETA ARE :":PRINT:PRINT
4050 LPRINT"THE CONFIDENCE INTERVALS, OR MEASUREMENT OF THE PRECISION OF THE"
4055 LPRINT"ESTIMATION OF BETA AND ETA ARE :":LPRINT:LPRINT
4100  PRINT"                  ";LIMITB1;" <= BETA <= ";LIMITB2:PRINT
4200 LPRINT"                  ";LIMITB1;" <= BETA <= ";LIMITB2:PRINT
4300  PRINT"                  ";LIMITE1;" <= ETA  <= ";LIMITE2:PRINT:PRINT
4400 LPRINT"                  ";LIMITE1;" <= ETA  <= ";LIMITE2:LPRINT:LPRINT
```

```
4450 LPRINT"FOR BETA AND ETA ESTIMATES OF";BH;"AND";EH;"AND A CONFIDENCE LEVEL O
F";A1:LPRINT:LPRINT:LPRINT
4451 LPRINT"$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$":L
PRINT:LPRINT
4500 PRINT"DO YOU WANT CONFIDENCE INTERVALS FOR OTHER VALUES OF BETA AND ETA
             (ANSWER Y OR N)";:INPUT A$
4600 IF A$="N" THEN GOTO 5100
4700 IF A$="Y" THEN GOTO 5000
4800 IF A$ <> "Y" GOTO 4900
4900 IF A$ <> "N" GOTO 4500
5000 CLS:GOTO 2400
5100 CLS
5150 CLOSE
5200 PRINT"YOU MAY NOW CALCULATE THE CONFIDENCE INTERVAL FOR THE TIME TO FIRST F
AILURE"
5300 PRINT"IF YOU HAVE CALCULATED THIS TIME TO FAIL PREVIOUSLY.  IF YOU HAVE NOT
"
5400 PRINT"CALCULATED THE TIME TO FIRST FAILURE YET, PROCEED TO THE MENU.":PRINT
:PRINT
5500 PRINT"                1.  CALCULATE CONFIDENCE INTERVAL FOR TIME TO FIRST
FAILURE.":PRINT
5600 PRINT"                2.  RETURN TO MENU.":PRINT:PRINT
5700 PRINT"WHAT IS YOUR CHOICE";:INPUT X1
5800 IF X1=1 THEN CHAIN "CNFINTFF"
5900 IF X1=2 THEN CHAIN "WEIBER"
6000 IF X1 <> 1 THEN 6100
6100 IF X1 <> 2 THEN 6200
6200 CLS:GOTO 5200
9999 PRINT"SAVING CNFINTBE ON DISK B":SAVE "B:CNFINTBE":END
```

```
3    CLS
4    REM
5    REM
6    REM $$$$$$$$$$$$$$$$$$$$$$$$$$ PROGRAM CNFINTFF $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
7    REM
8    REM
10   REM
50    PRINT"                 CONFIDENCE INTERVAL CALCULATION"
60    PRINT"                                FOR"
70    PRINT"                       TIME TO FIRST FAILURE"
80    PRINT"              WRITTEN BY JAMES L. BYERS, CODE 6052"
90    PRINT"                   NAVAL AIR DEVELOPMENT CENTER"
100   PRINT"                      WARMINSTER, PA 18974"

105   PRINT"                     VERSION OF 03 OCT 1986"
110  LPRINT"                 CONFIDENCE INTERVAL CALCULATION"
120  LPRINT"                                FOR"
130  LPRINT"                       TIME TO FIRST FAILURE"
140  LPRINT"              WRITTEN BY JAMES L. BYERS, CODE 6052"
150  LPRINT"                   NAVAL AIR DEVELOPMENT CENTER"
160  LPRINT"                      WARMINSTER, PA 18974"

170  LPRINT"                     VERSION OF 03 OCT 1986"
180  REM
190  REM
200  REM
210  PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
400  PRINT"WHAT IS THE VALUE OF BETA TO BE USED IN THIS ANALYSIS";:INPUT BH:PRIN
T:PRINT
450  LPRINT"VALUE OF BETA USED IS :";BH:LPRINT:LPRINT
500  PRINT"WHAT IS THE VALUE OF ETA TO BE USED IN THIS ANALYSIS";:INPUT EH:PRINT
:PRINT
550  LPRINT"VALUE OF ETA USED IS  :";EH:LPRINT:LPRINT
600  PRINT"WHAT NUMBER OF FAILURES ARE THESE VALUES OF BETA AND ETA BASED ON";:
     INPUT N1:PRINT:PRINT
650  LPRINT"NUMBER OF FAILURES BETA AND ETA ARE BASED ON IS :";N1:LPRINT:LPRINT
700  PRINT"WHAT IS THE ESTIMATED (CALCULATED) VALUE OF TIME TO FIRST FAILURE";:
     INPUT FFTE
750  LPRINT"ESTIMATED (CALCULATED) VALUE OF TIME TO FIRST FAILURE IS :";FFTE:LPR
INT:LPRINT:LPRINT
800  IF N1=1 THEN RANK5=.05
900  IF N1=2 THEN RANK5=.025
1000 IF N1=3 THEN RANK5=.016
1100 IF N1=4 THEN RANK5=.012
1200 IF N1=5 THEN RANK5=.01
1300 IF N1=6 THEN RANK5=8.000001E-03
1400 IF N1=7 THEN RANK5=.007
1500 IF N1=8 THEN RANK5=.006
1600 IF N1=9 THEN RANK5=.005
1700 IF N1=10 THEN RANK5=.005
```

```
1800 IF N1=10 THEN RANKNF=.258
1900 IF N1=9 THEN RANKNF=.283
2000 IF N1=8 THEN RANKNF=.312
2100 IF N1=7 THEN RANKNF=.348
2200 IF N1=6 THEN RANKNF=.393
2300 IF N1=5 THEN RANKNF=.45
2400 IF N1=4 THEN RANKNF=.527
2500 IF N1=3 THEN RANKNF=.631
2600 IF N1=2 THEN RANKNF=.776
2700 IF N1=1 THEN RANKNF=.95
2800 IF N1=22 THEN RANK5=.002
2900 IF N1=23 THEN RANK5=.002
3000 IF N1=24 THEN RANK5=.002
3100 IF N1=25 THEN RANK5=.002
3200 IF N1>25 THEN RANK5=.001
3300 IF N1>10 THEN RANKNF=(2.31467)*(1/N1^.941589)
3400 IF 10<N1<25 THEN RANK5=(.0630715)*(1/N1^1.13671)
3500 LIMITFF1=EH*(LOG(1/(1-RANK5)))^(1/BH)
3600 LIMITFF2=EH*(LOG(1/(1-RANKNF)))^(1/BH)
3700 PRINT:PRINT:PRINT:LPRINT:LPRINT:LPRINT
3800 CLS
3900 PRINT"THE CONFIDENCE INTERVAL, OR MEASUREMENT OF PRECISION OF THE"
4000 PRINT"ESTIMATE OF THE TIME TO FIRST FAILURE IS :":PRINT:PRINT
4100 PRINT"                    ";LIMITFF1;"<= TIME TO FIRST FAILURE <=";LIMITFF2:P
RINT:PRINT
4150 LPRINT"THE CONFIDENCE INTERVAL, OR MEASUREMENT OF PRECISION OF THE"
4155 LPRINT"ESTIMATE OF THE TIME TO FIRST FAILURE IS :":LPRINT
4160 LPRINT"                    ";LIMITFF1;"<= TIME TO FIRST FAILURE <=";LIMITFF2:L
PRINT:LPRINT
4200 PRINT"THE ESTIMATED VALUE OF TIME TO FIRST FAILURE IS :";FFTE:PRINT:PRINT
4250 LPRINT"THE ESTIMATED VALUE OF TIME TO FIRST FAILURE IS :"FFTE:LPRINT:LPRINT
4300 PRINT"DO YOU HAVE MORE CONFIDENCE INTERVALS TO CALCULATE (ANSWER Y OR N)";:
INPUT A$
4400 IF A$="Y" THEN 3
4500 IF A$="N" THEN CLS
4600 PRINT"PLEASE INPUT -99 TO RETURN TO THE MENU, OR -1111 TO QUIT."
4700 PRINT:PRINT
4800 PRINT"                                        YOUR CHOICE";:
     INPUT A1
4900 IF A1=-99 THEN CHAIN "WEIBER"
5000 IF A1=-1111 THEN CLS
9998 END
9999 CLS:PRINT"SAVING CNFINTFF ON DISK B":SAVE "B:CNFINTFF":END
```

```
5    CLS
10   '
20   '
30   '
40   REM ##################### PROGRAM RELIABTY ##################################
50   '
60   '
70   '
80   PRINT "                              RELIABILITY"
90   PRINT "                CALCULATES RELIABILITY AS A FUNCTION OF TIME"
100  PRINT "                   WRITTEN BY JAMES L. BYERS, CODE 6052"
110  PRINT "                      NAVAL AIR DEVELOPMENT CENTER"
120  PRINT "                          WARMINSTER, PA 18974"

140  LPRINT"                              RELIABILITY"
150  LPRINT"                CALCULATES RELIABILITY AS A FUNCTION OF TIME"
160  LPRINT"                   WRITTEN BY JAMES L. BYERS, CODE 6052"
170  LPRINT"                      NAVAL AIR DEVELOPMENT CENTER"
180  LPRINT"                          WARMINSTER, PA 18974"

200  PRINT:PRINT
210  PRINT "INPUT THE VALUE OF BETA (WEIBULL SLOPE) TO USE";:INPUT BETA
220  PRINT
230  PRINT "INPUT THE VALUE OF ETA (CHARACTERISTIC LIFE) TO USE";:INPUT ETA
240  PRINT
250  PRINT "INPUT THE TIME FOR WHICH YOU WANT THE RELIABILITY CALCULATED";:INPUT
 TIME
750  RELIABTY=EXP(-(TIME/ETA)^(BETA))
990  PRINT:PRINT
995  LPRINT:LPRINT:LPRINT
996  LPRINT
1000 PRINT "THE RELIABILITY AT TIME";TIME;"IS";RELIABTY
1005 LPRINT"THE RELIABILITY AT TIME";TIME;"IS";RELIABTY
1006 PRINT "THE PROBABILITY OF FAILURE AT THIS TIME IS";(1-RELIABTY)
1007 LPRINT"THE PROBABILITY OF FAILURE AT THIS TIME IS";(1-RELIABTY)
1010 PRINT:PRINT:PRINT"THE VALUES OF BETA AND ETA USED WERE";BETA;"AND";ETA
1015 LPRINT:LPRINT:LPRINT"THE VALUES OF BETA AND ETA USED WERE";BETA;"AND";ETA
1020 PRINT:PRINT:PRINT:PRINT"DO YOU WISH TO CALCULATE THE RELIABILITY FOR ANOTHE
R TIME (ANSWER Y OR N)";:INPUT A$
1025 CLS
1030 IF A$="Y" THEN 200
1040 IF A$="N" THEN 2000
1100 IF A$<>"N" THEN CLS:GOTO 1020
2000 PRINT
2005 PRINT:PRINT
2010 PRINT "DO YOU WISH TO CALCULATE THE CONFIDENCE INTERVAL FOR RELIABILITY"
2020 PRINT "(ANSWER Y OR N)";:INPUT A$
2030 CLS
2040 IF A$ = "Y" THEN CHAIN "CNFINREL"
2050 IF A$ = "N" THEN CHAIN "WEIBER"
2100 IF A$<>"N" THEN 2010
9998 END
9999 CLS:PRINT"SAVING RELIABTY ON DISK B":SAVE"B:RELIABTY"
```

```
5    CLS
10   '
20   '
30   '
40   REM ********************** PROGRAM CNFINREL ******************************
50   '
60   '
70   '
80   PRINT "                    CONFIDENCE INTERVAL CALCULATION"
90   PRINT "                                  FOR"
100  PRINT "                              RELIABILITY"
110  PRINT "                 WRITTEN BY JAMES L. BYERS, CODE 6052"
120  PRINT "                      NAVAL AIR DEVELOPMENT CENTER"
130  PRINT "                          WARMINSTER, PA 18974"

137  PRINT
140  PRINT "                        VERSION OF 24 FEB 1987"
150  LPRINT"                    CONFIDENCE INTERVAL CALCULATION"
160  LPRINT"                                  FOR"
170  LPRINT"                              RELIABILITY"
180  LPRINT"                 WRITTEN BY JAMES L. BYERS, CODE 6052"
190  LPRINT"                      NAVAL AIR DEVELOPMENT CENTER"
200  LPRINT"                          WARMINSTER, PA 18974"

207  LPRINT
210  LPRINT"                        VERSION OF 24 FEB 87"
220  PRINT:PRINT:PRINT:PRINT
230  PRINT "INPUT THE VALUE OF BETA (WEIBULL SLOPE) TO USE";:INPUT BETA
240  PRINT
250  PRINT "INPUT THE VALUE OF ETA (CHARACTERISTIC LIFE) TO USE";:INPUT ETA
260  PRINT
270  PRINT "INPUT THE TIME FOR WHICH YOU WANT THE CONFIDENCE INTERVAL CALCULATED
";:INPUT TIME
274  PRINT
280  PRINT "INPUT THE SAMPLE SIZE ON WHICH BETA AND ETA ARE BASED";:INPUT SAMPSI
ZE
290  PRINT
300  PRINT "WHICH CONFIDENCE LEVEL (0.99, 0.95, OR 0.90) DO YOU WISH TO USE TO"
310  PRINT "ESTABLISH A CONFIDENCE INTERVAL AROUND THE RELIABILITY";:INPUT A1:PR
INT:PRINT
320  IF A1=.99 THEN Z=2.576
330  IF A1=.95 THEN Z=1.96
340  IF A1=.9 THEN Z=1.645
350  RELIABTY=EXP(-(TIME/ETA)^(BETA))
360  UHAT=(LOG(TIME)-LOG(ETA))*BETA
370  VARUHAT=(1.168+1.1*(UHAT)^2-.1913*(UHAT))*(1/SAMPSIZE)
380  U1=UHAT-Z*ABS((VARUHAT))^.5
390  U2=UHAT+Z*ABS((VARUHAT))^.5
410  PRINT:PRINT:PRINT
415  LPRINT:LPRINT:LPRINT
```

```
420  PRINT "                    ";EXP(-EXP(U2));"<= RELIABILITY <= ";EXP(-EXP(U1))
:PRINT
425  LPRINT"                    ";EXP(-EXP(U2));"<= RELIABILITY <= ";EXP(-EXP(U1))
:LPRINT
430  PRINT:PRINT"WHERE RELIABILITY IS";RELIABTY;"FOR BETA =";BETA;", ETA =";ETA;
", AND TIME =";TIME
435  LPRINT:LPRINT"WHERE RELIABILITY IS";RELIABTY;"FOR BETA =";BETA;", ETA =";ET
A;", AND TIME =";TIME
440  PRINT:PRINT:PRINT
450  PRINT "DO YOU WISH TO CALCULATE THE CONFIDENCE INTERVAL FOR ANOTHER TIME -"
460  PRINT "(ANSWER Y OR N)";:INPUT A$
465  CLS
470  IF A$ = "Y" THEN 220
480  IF A$ = "N" THEN CHAIN "WEIBER"
500 IF A$<>"N" THEN 450
9998 END
9999 CLS:PRINT"SAVING CNFINREL ON DISK B":SAVE"B:CNFINREL"
```

```
2 REM ..................PROGRAM BETAHIST..................................
3 REM
4 REM
5 LPRINT:LPRINT:LPRINT:LPRINT
6 CLS:PRINT:PRINT:PRINT:PRINT:PRINT"PRINTING HARD COPY OF HISTORICAL VALUES OF B
ETA (WEIBULL SLOPE)."
10 LPRINT"************VALUES OF BETA (WEIBULL SLOPE) FROM HISTORICAL TRENDS*****
*******"
20 LPRINT:LPRINT:LPRINT
30 LPRINT"* BEARINGS, GENERAL FAILURES...........................1.5"
40 LPRINT"* CRACK, FLANGE........................................9.5"
50 LPRINT"* EROSION, TURBINE VANE................................3.0"
60 LPRINT"* LCF, COMPRESSOR CASE.................................5.0"
70 LPRINT"* LCF, COMPRESSOR DISK.................................3.0"
85 LPRINT"* LCF, NOZZLE BEARING..................................1.5"
86 LPRINT"* LCF, GENERAL.........................................2.0--->5.0"
90 LPRINT"* PERFORMANCE DETERIORATION............................4.0--->5.0"
100 LPRINT"* ROTATING STRUCTURE..................................6.0--->8.0"
110 LPRINT"* STATIC STRUCTURE....................................4.0--->6.0"
120 LPRINT"* THERMAL LCF, COMBUSTOR..............................3.0"
130 LPRINT:LPRINT:LPRINT
140 LPRINT"* INDEPENDENT OF TIME"
150 LPRINT"* INGESTION (FOD) AND MISUSE"
160 LPRINT"* INSUFFICIENT REDUNDENCY"
170 LPRINT"* MAINTENANCE ERRORS"
180 LPRINT"* MIXTURE OF PROBLEMS"
190 LPRINT"* ORIGINAL DESIGN DEFICIENCIES"
200 LPRINT"* RANDOM FAILURES.....................................1.0"
210 LPRINT:LPRINT:LPRINT
220 LPRINT"* SLOPES LESS THAN 1.0 ARE INFANT MORTALITY WHERE RELIABILITY WILL IN
CREASE"
230 LPRINT"WITH AGE.  ALSO INDICATES A QUALITY PROBLEM SUCH AS MISASSEMBLY.  USU
ALLY"
240 LPRINT"HAS A VALUE AROUND 0.5."
250 LPRINT
260 LPRINT"* SLOPES GREATER THAN 1.0 ARE GENERALLY WEAROUT FOR ONE REASON OR ANO
THER."
270 LPRINT
280 LPRINT"* A SLOPE OF 2.5 IS USUALLY GRADUAL WEAROUT."
290 LPRINT
300 LPRINT"* A SLOPE OF 3.44 APPROXIMATES A BELL SHAPED CURVE (NORMAL DISTRIBUTI
ON)."
310 LPRINT
320 LPRINT"* SLOPES GREATER THAN ABOUT 4.5 ARE USUALLY RAPID WEAROUT (BRICK WALL
)."
500 CHAIN "WEIBER"
9998 END
9999 CLS:PRINT"SAVING BETAHIST ON DISK B":SAVE"B:BETAHIST"
```

```
100 CLS
110 LPRINT"                    WEIBULL PARAMETER CALCULATION"
120 LPRINT"                 PRATT & WHITNEY AIRCRAFT - GPD - UTC"
130 LPRINT"               AS IMPROVED BY JAMES L. BYERS, CODE 6052"
140 LPRINT"                 NAVAIRDEVCEN, WARMINSTER, PA 18974"

INT
150 LPRINT"                          VERSION 18 FEB 1987"
155 LPRINT:LPRINT
160 DIM IS(100),RA(100),A(100),RO(100),TT(100),XZ(100)
165 DIM YX(100),IN(100),TI(100),V(100),IZ(100),X(100)
170 CLS:PRINT"                   WEIBULL PARAMETER CALCULATION"
180 PRINT"               PRATT & WHITNEY AIRCRAFT -GPD - UTC"
190 PRINT"             AS IMPROVED BY JAMES L. BYERS, CODE 6052"
200 PRINT"               NAVAIRDEVCEN, WARMINSTER, PA 18974"

220 IP=0
230 IM=0
240 PRINT:PRINT:PRINT:PRINT:PRINT"            ARE YOU INPUTTING A HISTOGRAM O
F SUSPENSIONS?":PRINT:PRINT
250 PRINT"                         ANSWER Y OR N";:INPUT A$
260 IF A$="N" GOTO 470
261 IF A$="Y" GOTO 270
262 CLS:IF A$<>"Y" GOTO 240
270 IP=1
280 CLS:PRINT:PRINT"              AN INTERVAL SIZE IF 50 IS ASSUMED."
290 PRINT:PRINT:PRINT"            O.K.?............ANSWER Y OR N";:INPUT
 A$
295 IF A$="Y" GOTO 330
300 IF A$ <> "Y" GOTO 310
310 PRINT:PRINT:PRINT"             INPUT THE INTERVAL SIZE YOU WILL USE"
320 PRINT:PRINT:PRINT"                          WITH DECIMAL.";:INPUT PE
330 PRINT:PRINT:PRINT"    PLACE THE NUMBER OF PARTS OR COMPONENTS IN EACH IN
TERVAL OF"
340 PRINT"                             THE HISTOGRAM."
350 PRINT:PRINT"             INPUT -99 TO INDICATE THE END OF THE DATA"
360 M=0
370 M=M+1
380 INPUT XI
390 IF XI=-99 GOTO 410
400 IN(M)=XI:GOTO 370
410 MM=M-1
420 FOR I=1 TO MM:PRINT IN(I);:NEXT I:PRINT
430 IM=0
440 FOR J=1 TO MM
450 TI(J)=PE/2!+(J-1)*PE
460 IM=IM+IN(J):NEXT J
470 CLS:PRINT:PRINT:PRINT"INPUT THE FAILURE DATA AND SUSPENSIONS WITH DECIMAL...
USE -99999 TO"
480 PRINT"INDICATE THE END OF THE DATA (NEGATIVES INDICATE SUSPENSIONS, UNLESS A
"
490 PRINT"HISTOGRAM WAS INPUT)":PRINT:PRINT:PRINT
```

```
500 I=0
510 I=I+1
520 INPUT A(I)
530 IF A(I)=0! GOTO 560
540 IF A(I)=-99999! GOTO 580
550 GOTO 510
560 I=I-1
570 GOTO 510
580 N=I-1
590 BN=N+IM
600 FOR J=1 TO N:AN=A(J):V(J)=ABS(AN):NEXT J
610 GOSUB 1880
620 FOR I=1 TO N:IU=IZ(I):X(I)=A(IU):NEXT I
630 FOR I=1 TO N:A(I)=X(I):NEXT I
640 B1=BN+1:DJ=1!:BJ=0!:M=0:SX=0!:SY=0!:XX=0!:YY=0!:XY=0!
650 PRINT:PRINT
660 PRINT"POINT         DATA         ORDER            MEDIAN RANK":PRINT
670 LPRINT"POINT         DATA         ORDER            MEDIAN RANK":LPRINT
680 FOR K=1 TO N
690 IM=0
700 IF IP=0 GOTO 750
710 FOR J=1 TO MM
720 IF TI(J) < A(K) THEN IM=IM+IN(J)
730 NEXT J
740 IS(K)=IM
750 BK=IM+K
760 IF IP=1 THEN BK=BK-1!
770 IF IP=1 AND K=1 THEN DJ=(B1-BJ)/(B1-BK)
780 IF K=1 GOTO 820
790 IF IP=0 GOTO 820
800 IF IS(K)=IS(K-1) GOTO 820
810 DJ=(B1-BJ)/(B1-BK)
820 IF A(K) < 0! GOTO 850
830 IF A(K)=0! GOTO 1160
840 IF A(K) > 0! GOTO 860
850 DJ=(B1-BJ)/(B1-BK):GOTO 920
860 BJ=BJ+DJ:RO(K)=BJ:RA(K)=(RO(K)-.3)/(BN+.4)
870 X1=LOG(A(K)):YP=1!/(1!-RA(K)):Y=LOG(LOG(YP)):YX(K)=Y
880 PRINT K,A(K),RO(K),RA(K)
890 LPRINT K,A(K),RO(K),RA(K)
900 M=M+1
910 SX=SX+X1:XX=XX+X1*X1:SY=SY+Y:YY=YY+Y*Y:XY=XY+X1*Y
920 NEXT K
930 PRINT:PRINT
940 LPRINT:LPRINT
950 GM=M
960 BE=(GM*YY-SY*SY)/(GM*XY-SX*SY)
970 AL=(BE*SX-SY)/GM:AV=AL/BE:AV=EXP(AV):ST=BE
980 PRINT"BETA=";ST,"ETA=";AV
990 PRINT:PRINT
1000 LPRINT"BETA=";ST,"ETA=";AV
1010 LPRINT:LPRINT
1020 R=0!
1030 IF (XX-SX*SX/GM) < 0! GOTO 1070
1040 XN=XY-SX*SY/GM
1050 DE=SQR((XX-SX*SX/GM)*(YY-SY*SY/GM))
```

```
1060 R=XN/DE
1070 RQ=R*R
1080 IF RQ > 1! THEN RQ=1!
1090 PRINT:PRINT:PRINT"DO YOU WISH TO DO A MAXIMUM LIKELIHOOD ESTIMATION?"
1100 PRINT"ANSWER Y OR N";:INPUT A$
1105 IF A$="Y" THEN 1120
1110 IF A$="N" GOTO 1131
1111 IF A$<>"N" THEN 1090
1120 CLS:NF=0:PRINT:PRINT:PRINT:PRINT"          PLEASE BE PATIENT..........IT'S
 ITERATING.":PRINT:PRINT:PRINT
1130 GOSUB 1180
1131 PRINT:PRINT:PRINT:PRINT"DO YOU HAVE ANOTHER ANALYSIS TO DO?"
1132 PRINT:PRINT"ANSWER Y OR N";:INPUT A$:IF A$="Y" THEN 170
1135 IF A$="N" THEN 1160
1136 IF A$<>"N" THEN CLS:GOTO 1131
1140 PRINT:PRINT:PRINT"PRESS ENTER TO RETURN TO MENU";:INPUT A$
1150 IF A$<>"" GOTO 1140
1160 CHAIN "WEIBER"
1170 END
1180 FOR I=1 TO N
1190 TT(I)=ABS(A(I))
1200 IF A(I) < 0! GOTO 1230
1210 NF=NF+1
1220 XZ(NF)=A(I)
1230 NEXT I
1240 OT=.0001:NL=100:XB=BE:YA=.001:NC=0:DX=.001:DY=.01
1250 GOSUB 1430:YB=AU
1260 GOSUB 1560:XB=BB0
1270 ON JK GOTO 1250,1340,1290,1340
1280 GOTO 1250
1290 PRINT"ITERATION FAILURE"
1300 LPRINT"ITERATION FAILURE"
1310 PRINT"BETA=";XB,"LN MAXIMUM LIKELIHOOD=";YB
1320 LPRINT"BETA=";XB;,"LN MAXIMUM LIKELIHOOD=";YB
1330 RETURN
1340 BL=XB:SU=0!:RN=NF:FOR I=1 TO N:SU=SU+TT(I)^BL:NEXT I
1350 IF IP=0 GOTO 1370
1360 FOR I=1 TO MM:SU=SU+IN(I)*TI(I)^BL:NEXT I
1370 SU=SU/RN:TL=SU^(1!/BL)
1380 PRINT"MAXIMUM LIKELIHOOD ESTIMATES FOLLOW"
1390 PRINT:PRINT:PRINT"BETA=";BL,"ETA=";TL
1400 LPRINT:LPRINT"MAXIMUM LIKELIHOOD ESTIMATES FOLLOW:":LPRINT
1410 LPRINT"BETA=";BL,"ETA=";TL
1420 RETURN
1430 S10=0!:S20=0!:S30=0!
1440 IF XB > 15 OR XB <= 0! THEN XB=.1
1450 FOR I=1 TO N
1460 PO0=TT(I)^XB
1470 S10=S10+PO0
1480 S20=S20+LOG(TT(I))*PO0
1490 NEXT I
1500 IF IP=0 GOTO 1530
1510 FOR I=1 TO MM:PO0=TI(I)^XB:S10=S10+IN(I)*PO0
1520 S20=S20+IN(I)*LOG(TI(I))*PO0:NEXT I
1530 FOR I=1 TO NF:S30=S30+LOG(XZ(I)):NEXT I
1540 AU=(S20/S10)-(S30/NF)-(1!/XB)
1550 RETURN
```

```
1560 JK=1:BB0=XB
1570 IF(ABS((YA-YB)/YA)-OT) <= 0! GOTO 1840
1580 IF (NC-1) <= 0 GOTO 1600
1590 GOTO 1650
1600 DX0=BB0
1610 DY0=YA-YB
1620 NC=NC+1
1630 BB0=BB0*1.02
1640 RETURN
1650 IF NC > NL GOTO 1850
1660 X20=BB0
1670 D20=YA-YB
1680 IF ABS(D20-DY0) < .00001 GOTO 1870
1690 BB0=X20-D20*(X20-DX0)/(D20-DY0)
1700 IF BB0 <= 0! GOTO 1800
1710 IF BB0 < X20 GOTO 1740
1720 IF BB0=X20 GOTO 1790
1730 IF BB0 > X20 GOTO 1760
1740 IF BB0/X20 >= .6 GOTO 1800
1750 BB0=X20*.75:GOTO 1800
1760 IF BB0/X20 < 1.4 GOTO 1800
1770 BB0=X20*1.25
1780 GOTO 1800
1790 BB0=X20*1.02
1800 DX0=X20
1810 DY0=D20
1820 NC=NC+1
1830 RETURN
1840 JK=2:NC=2:RETURN
1850 PRINT"FAILED TO CONVERGE"
1860 JK=3:NC=1:RETURN
1870 JK=4:RETURN
1880 FOR J=1 TO N:IZ(J)=J:NEXT J
1890 IF N=1 THEN RETURN
1900 NM=N-1
1910 FOR K=1 TO N
1920 FOR J=1 TO NM
1930 N1=IZ(J)
1940 N2=IZ(J+1)
1950 IF V(N1) < V(N2) GOTO 1970
1960 IZ(J+1)=N1:IZ(J)=N2
1970 NEXT J
1980 NEXT K
1990 RETURN
9998 END
9999 CLS:PRINT"SAVING PWAWEIBL ON DISK B":SAVE "B:PWAWEIBL"
```

```
30 REM #################### PROGRAM BIGWEIBL ##################################
70 CLS
1400 GOTO 17300
1900 DIM ETA(4)
1950 Y=1100
2000 DIM BETA(4)
2050 DIM FAIL(Y)
2055 DIM BIGF(Y)
2100 DIM N(Y)
2200 DIM TT(Y)
2300 DIM T(Y)
2400 DIM BUST(150)
2500 DIM MTF(Y)
2600 DIM F(Y)
2700 DIM TF(Y,4)
2800 DIM RUNFAIL(X)
2950 RANDOMIZE Z
3000 TOTFAIL=0
3100 FOR K=1 TO J
3200 READ BETA(K)
3300 NEXT K
3400 FOR K=1 TO J
3500 READ ETA(K)
3600 NEXT K
3700 FOR K=1 TO S
3800 READ N(K),T(K)
4100 NEXT K
4200 RESTORE
4300 SUM=0
4400 TMAX=UTR*MOI
4450 LPRINT:LPRINT:LPRINT
4500 LPRINT"                          WEIBULL RISK ANALYSIS"
4600 LPRINT"                        A MONTE CARLO SIMULATION"
4700 LPRINT"                                BIGWEIBL":LPRINT:LPRINT
4800 LPRINT"                             ENGINE :";E$:LPRINT:LPRINT:LPRINT
4900 LPRINT"BETA VALUES :"
5000 FOR Y=1 TO J:LPRINT BETA(Y),:NEXT Y:LPRINT:LPRINT:LPRINT
5100 LPRINT"ETA VALUES :"
5200 FOR Y=1 TO J:LPRINT ETA(Y),:NEXT Y:LPRINT:LPRINT:LPRINT
5300 LPRINT"DATA PAIRS :"
5400 LPRINT"NO. ENGS.";"     INIT. TIME"
5500 FOR Y=1 TO S:LPRINT"    ";N(Y),T(Y):NEXT Y:LPRINT:LPRINT:LPRINT
5600 PRINT"MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS";TMAX;"HOURS"
:PRINT:LPRINT"MAXIMUM OPERATING HOURS PER ENGINE FOR THIS ANALYSIS IS";TMAX;"HOU
RS":LPRINT
5700 PRINT"INSPECTION INTERVAL FOR THIS ANALYSIS IS";INSPT;"HOURS":PRINT:LPRINT"
INSPECTION INTERVAL FOR THIS ANALYSIS IS";INSPT;"HOURS":LPRINT
5800 PRINT"TIME DURATION OF THIS ANALYSIS IS";MOI;"MONTHS":LPRINT"TIME DURATION
OF THIS ANALYSIS IS";MOI;"MONTHS":LPRINT:PRINT
5900 PRINT"UTILIZATION RATE IS";UTR;"HOURS PER ENGINE PER MONTH":PRINT:LPRINT"UT
ILIZATION RATE IS";UTR;"HOURS PER ENGINE PER MONTH":LPRINT
6000 FOR L=1 TO S
6100 PRINT" ###################### DATA PAIR NUMBER";L;" #########################
##":PRINT:PRINT
6200 LPRINT" ###################### DATA PAIR NUMBER";L;" ########################
###":LPRINT:LPRINT
```

```
6250 PRINT:PRINT:PRINT:PRINT"            PLEASE BE PATIENT ------ I'M COMPUT
ING THE FAILURES"
6300 FOR M=1 TO X
6400 PRINT M
6600 FOR I=1 TO N(L)
6700 PRINT I,
7000 FOR K=1 TO J
7100 TF(I,K)=ETA(K)*(LOG(1/(1-RND(Z))))^(1/(BETA(K)))
7200 IF TF(I,K)<T(L) THEN 7100
7300 IF TF(I,K)<INSPT THEN 7500
7400 IF TF(I,K)>INSPT THEN 7800
7500 Q(K)=1:BUST(K)=BUST(K)+Q(K):Q(K)=0
7800 NEXT K
7900 GOSUB 10000
8000 GOTO 13500
9000 SUM=SUM+FAILS
9100 TOTFAIL=TOTFAIL+SUM
9200 RUNFAILS=RUNFAILS+SUM
9300 FAIL(I)=FAIL(I)+FAILS
9600 FAILS=0
9700 SUM=0
9910 BIGF(I)=BIGF(I)+FAIL(I):FAIL(I)=0:TT(I)=0
9920 GOTO 15000
10000 FOR A=1 TO J-1
10100 B=A
10200 FOR C=A+1 TO J
10300 IF TF(I,C)<TF(I,B) THEN 10500
10400 GOTO 10600
10500 B=C
10600 NEXT C
10700 D=TF(I,A)
10800 TF(I,A)=TF(I,B)
10900 TF(I,B)=D
11000 NEXT A
11100 RETURN
12000 FOR K=1 TO J
12100 TF(I,K)=ETA(K)*(LOG(1/(1-RND(Z))))^(1/(BETA(K)))
12400 IF TF(I,K)<INSPT THEN 12500 ELSE 12600
12500 Q(K)=1:BUST(K)=BUST(K)+Q(K):Q(K)=0
12600 NEXT K
12610 GOSUB 10000
13500 IF TF(I,1)<INSPT AND (TF(I,1)+TT(I))<TMAX THEN FAILS=FAILS+1
13600 IF TF(I,1)>INSPT THEN TF(I,1)=INSPT
13700 TT(I)=TT(I)+TF(I,1)
13800 IF TT(I)=>TMAX THEN TT(I)=TMAX
14100 IF TT(I)=>TMAX THEN 9000 ELSE 12000
14900 PRINT I,
15000 NEXT I
15200 RUNFAIL(M)=RUNFAILS
15300 SUM=0:FAILS=0:RUNFAILS=0
15350 PRINT M
15400 NEXT M
15650 CLS
15700 SUM=TOTFAIL/X:LPRINT:LPRINT"AVERAGE NUMBER FAILURES";X;"ITERATIONS = ";SUM
:LPRINT:LPRINT
15800 PRINT"AVERAGE NUMBER FAILURES";X;"ITERAIONS = ";SUM:PRINT
15900 TOTFAIL=0:SUM=0
```

```
16000 FOR M=1 TO X
16100 PRINT"NUMBER OF FAILURES IN ITERATION";M;"=";RUNFAIL(M);:PRINT
16200 NEXT M
16300 FOR R=1 TO N(L):BIGF(R)=BIGF(R)/X:NEXT R
16400 PRINT
16500 FOR M=1 TO X:LPRINT"NUMBER OF FAILURES IN ITERATION";M;"=";RUNFAIL(M):LPRI
NT:NEXT M
16600 LPRINT:FOR R=1 TO N(L):BIGF(R)=0:NEXT R
16800 NEXT L
16900 GOTO 28500
17300 CLS:PRINT"THIS IS THE DATA INPUT SECTION OF THE WEIBULL RISK CODE (SHORT V
ERSION)."
17400 PRINT
17500 PRINT"YOU WILL BE ASKED TO INPUT VARIOUS DATA IN A GIVEN FORMAT."
17600 PRINT
17700 PRINT"THE FORMAT IS CRITICAL SO FOLLOW INSTRUCTIONS CAREFULLY.":PRINT
17800 PRINT"TYPE 1 <ENTER> TO INPUT DATA.  TYPE -1 <ENTER> TO QUIT.  YOUR CHOICE
";
17900 INPUT Z1
18000 CLS
18100 IF Z1=-1 THEN 26100
18200 IF Z1=1 THEN 20200 ELSE 17800
20200 CLS
20300 PRINT"NOW TYPE THE FOLLOWING :":PRINT
20400 PRINT"25800 DATA BETA(1),BETA(2),...,BETA(J)"
20500 PRINT"          WHERE BETA(1) IS THE WEIBULL SLOPE FOR THE FIRST MODE OF"
20600 PRINT"          FAILURE, BETA(2) IS THE WEIBULL SLOPE FOR THE SECOND MODE"
20700 PRINT"          OF FAILURE, AND SO ON UNTIL THE NUMBER OF BETA'S CORRESPON
D"
20800 PRINT"          TO THE INTEGER FOR THE NUMBER OF FAILURE MODES.  SEPARATE"
20900 PRINT"          BETA'S WITH COMMA'S.":PRINT
21000 PRINT"AFTER THE LAST BETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 21300' AN
D"
21100 PRINT"<ENTER>."
21200 STOP
21300 CLS
21400 PRINT"NOW TYPE THE FOLLOWING :":PRINT
21500 PRINT"25900 DATA ETA(1),ETA(2),...,ETA(J)"
21600 PRINT"          WHERE ETA(1) IS THE CHARACTERISTIC LIFE FOR THE FIRST MODE
"
21700 PRINT"          OF FAILURE, ETA(2) IS THE CHARACTERISTIC LIFE FOR THE"
21800 PRINT"          SECOND MODE OF FAILURE, AND SO ON UNTIL THE NUMBER OF ETA'
S"
21900 PRINT"          CORRESPOND TO THE INTEGER FOR THE NUMBER OF FAILURE MODES.
"
22000 PRINT"          SEPARATE ETA'S WITH COMMA'S.":PRINT
22100 PRINT"AFTER THE LAST ETA IS TYPED, PRESS <ENTER> THEN TYPE 'RUN 22400' AND
"
22200 PRINT"<ENTER>."
22300 STOP
22400 CLS
```

```
22500 PRINT"NOW TYPE THE FOLLOWING :":PRINT
22600 PRINT"24000 DATA N1,T1,N2,T2,...etc."
22700 PRINT"          WHERE N1 IS THE NUMBER OF ENGINES AT TIME T1"
22800 PRINT"                T1 IS THE OPERATING TIME OF ENGINES N1"
22900 PRINT"                N2 IS THE NUMBER OF ENGINES AT TIME T2"
23000 PRINT"                T2 IS THE OPERATING TIME OF ENGINES N2, etc.":PRINT
23100 PRINT"USE ADDITIONAL LINES AS NEEDED TO ADD MORE DATA."
23200 PRINT"WHEN THE LAST DATA PAIR IS ENTERED, TYPE 'RUN 23400' AND <ENTER>."
23300 STOP
23400 CLS
23500 PRINT"NOW INPUT THE NUMBER OF DATA PAIRS JUST ENTERED.";:INPUT S:PRINT
23700 PRINT"INPUT THE TOTAL NUMBER OF ENGINES IN THE SAMPLE - NOT OVER 1100";:IN
PUT R:PRINT
23900 PRINT"INPUT THE NUMBER OF MONTHS THAT THIS ANALYSIS WILL COVER, i.e., 36 F
OR THREE    YEARS.";:INPUT MOI:PRINT
24200 PRINT"NEXT, INPUT THE OPERATING HOURS PER MONTH (AVERAGE) OVER THE TIME"
24300 PRINT"PERIOD OF THIS ANALYSIS.";:INPUT UTR:PRINT
24500 PRINT"INPUT THE INSPECTION INTERVAL FOR THE ENGINE OF THIS ANALYSIS.";:INP
UT INSPT:PRINT
24700 PRINT"INPUT THE NUMBER OF FAILURE MODES OF THIS ANALYSIS.";:INPUT J:PRINT
24900 PRINT"INPUT THE ENGINE DESIGNATION.";:INPUT E$:PRINT
24950 PRINT"INPUT ANY NUMBER BETWEEN +1 AND +32767 TO SEED THE RANDOM NUMBER GEN
ERATOR.    USE A DIFFERENT NUMBER FOR EACH ANALYSIS.";:INPUT Z:PRINT
24960 PRINT"LASTLY, INPUT THE NUMBER OF ITERATIONS TO BE PERFORMED DURING THE AN
ALYSIS.";:INPUT X
25100 CLS
25500 GOTO 1900
25800 DATA 3.55
25900 DATA 2741
26000 DATA 1000,0
26100 END
28500 PRINT:PRINT:PRINT"DO YOU HAVE OTHER ANALYSES TO DO - (Y) OR (N)";:INPUT A$
28510 IF A$="Y" THEN 17300
28520 IF A$="N" THEN CHAIN "WEIBER"
28550 CLS:GOTO 28500
29990 END
30000 CLS:PRINT:PRINT:PRINT"SAVING BIGWEIBL ON DISK B":SAVE "B:BIGWEIBL":END
```

```
10   CLS
15   PRINT"                          WEIBAYES ANALYSIS"
20   PRINT"                  WHEN WEIBULL PLOTS ARE IMPOSSIBLE"
25   PRINT"                    DUE TO A LACK OF FAILURE DATA"
30   PRINT"                      WRITTEN BY JAMES L. BYERS"
35   PRINT"               NAVAL AIR DEVELOPMENT CENTER, CODE 6052"
40   PRINT"                       WARMINSTER, PA 18974"

45   REM
50   REM
55   REM   ###################### PROGRAM WEIBAYES ##########################
60   REM
65   REM
70   LPRINT"                         WEIBAYES ANALYSIS"
75   LPRINT"                 WHEN WEIBULL PLOTS ARE IMPOSSIBLE"
80   LPRINT"                   DUE TO A LACK OF FAILURE DATA"
85   LPRINT"                     WRITTEN BY JAMES L. BYERS"
90   LPRINT"              NAVAL AIR DEVELOPMENT CENTER, CODE 6052"
95   LPRINT"                      WARMINSTER, PA 18974"

97  PRINT:PRINT:LPRINT:LPRINT
100  PRINT"DO YOU KNOW THE VALUE OF THE CHARACTERISTIC LIFE (INPUT <Y> OR <N>)";
110  INPUT A$
120  IF A$="N" THEN 500
130  IF A$="Y" THEN 1090
500  PRINT:PRINT:PRIN"
550  PRINT"YOU WILL NOW DIVERT TO THE 'ETACALC' PROGRAM IN ORDER TO CALCULATE"
560  PRINT"THE VAL'_ OF THE CHARACTERISTIC LIFE.  AFTER THE VALUE OF ETA IS"
570  PRINT"DETERMINED, MAKE A NOTE OF IT AND RELOAD THIS PROGRAM - WEIBAYES."
580  PRINT:PRINT"PRESS ENTER KEY TO CONTINUE."
700  INPUT W$:IF W$="" THEN CHAIN "ETACALC"
922 0 PRINT"EXPERIENCE IS OBTAINED WITHOUT A FAILURE (OR FEW FAILURES) SUCH THAT
 A"
1090 CLS
1100 PRINT:PRINT:PRINT:PRINT"DATA INPUT ------------ ENTER THE FOLLOWING:"
1200 PRINT:PRINT"4000 DATA BX"
1300 PRINT"                WHERE BX = THE PERCENT OF THE POPULATION ALLOWED"
1350 PRINT"                TO FAIL, i.e., 0.001 FOR B.1 LIFE"
1355 PRINT"                DO NOT USE 1.0 OR ANY PERCENT > 0.999999"
1400 PRINT:PRINT"4040 DATA B,H"
1500 PRINT"                WHERE B = THE ASSUMED VALUE OF THE WEIBULL SLOPE"
1550 PRINT"                'BETA' AND H = THE CALCULATED VALUE OF THE CHARACTERI
STIC"
1575 PRINT"                LIFE 'ETA'"
1845 PRINT"WHEN ALL DATA IS ENTERED, INPUT <RUN 1049> TO CONTINUE."
1846 STOP
1049 CLS
1050 READ BX
1060 READ BETA,ETA
1070 RESTORE
4000 DATA 0.999999
4040 DATA 3,1000
```

```
8000 L = (-LOG(1-BX))^(1/BETA)*ETA
8100 BXX = 1-(EXP((-(L/ETA))^(BETA)))
8110 BXX=BXX*100
8990 CLS
9000 PRINT"                              LIFE CALCULATION FOR WEIBAYES"
9010 PRINT:PRINT
9100 PRINT"PERCENT OF POPULATION ALLOWED TO FAIL =";BXX;"(CALCULATED VALUE)."
9170 PRINT:PRINT"THE CALCULATED LIFE USING THE INPUT VALUE OF BX IS EQUAL TO";L
9180 PRINT:PRINT"IF THIS VALUE IS SMALLER THAN ACCEPTABLE THEN THE CALCULATED VA
LUE OF"
9190 PRINT"ETA (CHARACTERISTIC LIFE) IS TOO SMALL.  THIS MAY BE DUE TO A LACK OF
"
9200 PRINT"SUFFICIENT OPERATING TIME USED IN THE CALCULATION OF ETA.  INSUFFICIE
NT"
9210 PRINT"DATA INDICATES A NEED TO EXERCISE CONSERVATISM UNTIL ENOUGH OPERATION
AL"
9220 PRINT"EXPERIENCE IS OBTAINED WITHOUT A FAILURE (OR FEW FAILURES) SUCH THAT
A"
9230 PRINT"HIGHER VALUE OF ETA IS CALCULATED."
9240 PRINT:PRINT"BETA USED WAS";BETA;"      ETA USED WAS";ETA;"."
9250 LPRINT"                              LIFE CALCULATION FOR WEIBAYES"
9255 LPRINT:LPRINT
9260 LPRINT"PERCENT OF POPULATION ALLOWED TO FAIL =";BXX;"(CALCULATED VALUE)."
9265 LPRINT:LPRINT"THE CALCULATED LIFE USING THE INPUT VALUE OF BX IS EQUAL TO";
L
9270 LPRINT:LPRINT"IF THIS VALUE IS SMALLER THAN ACCEPTABLE THEN THE CALCULATED
VALUE OF"
9275 LPRINT"ETA (CHARACTERISTIC LIFE) IS TOO SMALL.  THIS MAY BE DUE TO A LACK O
F"
9280 LPRINT"SUFFICIENT OPERATING TIME USED IN THE CALCULATION OF ETA.  INSUFFICI
ENT"
9285 LPRINT"DATA INDICATES A NEED TO EXERCISE CONSERVATISM UNTIL ENOUGH OPERATIO
NAL"
9290 LPRINT"EXPERIENCE IS OBTAINED WITHOUT A FAILURE (OR FEW FAILURES) SUCH THAT
 A"
9295 LPRINT"HIGHER VALUE OF ETA IS CALCULATED."
9297 LPRINT:LPRINT"BETA USED WAS";BETA;"      ETA USED WAS";ETA;"."
9300 PRINT:PRINT:PRINT"DO YOU HAVE ANOTHER CASE TO RUN, <Y> OR <N>";:INPUT I$
9310 IF I$ = "Y" THEN 97
9320 IF I$ = "N" THEN 9900
9330 CLS:GOTO 9300
9900 CHAIN "WEIBER"
9998 END
9999 CLS:PRINT:PRINT:PRINT"SAVING WEIBAYES ON DISK B";SAVE "B:WEIBAYES":END
```

```
5   CLS
6   K=1
10  PRINT"                    ZERO FAILURE TEST PLAN GENERATION"
15  PRINT"                NUMBER OF TEST UNITS AND TEST TIME FOR EACH"
30  PRINT"                  WRITTEN BY: JAMES L. BYERS, CODE 6052"
35  PRINT"                     NAVAL AIR DEVELOPMENT CENTER"
40  PRINT"                       WARMINSTER, PA 18974"

45  PRINT"                       VERSION  17 MAY 87"
46  IF K<>1 THEN 100
50  LPRINT"                   ZERO FAILURE TEST PLAN GENERATION"
55  LPRINT"               NUMBER OF TEST UNITS AND TEST TIME FOR EACH"
60  LPRINT"                            WRITTEN BY"
65  LPRINT"                 WRITTEN BY: JAMES L. BYERS, CODE 6052"
75  LPRINT"                    NAVAL AIR DEVELOPMENT CENTER"
80  LPRINT"                       WARMINSTER, PA 18974"


85  LPRINT"                       VERSION  17 MAY 87"
100 PRINT:PRINT"THIS CODE CALCULATES THE STATISTICAL REQUIREMENT FOR SUBSTANTIAT
ION TESTING THAT"
110 PRINT"DEMONSTRATES A REDESIGNED PART / SYSTEM HAS ELIMINATED OR SIGNIFICANTL
Y IMPROVED"
120 PRINT"A KNOWN FAILURE MODE  -  BETA AND ETA ARE ASSUMED TO BE KNOWN.":PRINT
130 PRINT"THE RESULTING TEST PLAN GIVES:"
140 PRINT"        1.  THE REQUIRED NUMBER OF TEST UNITS"
150 PRINT"        2.  TEST TIME TO BE ACCUMULATED ON EACH UNIT":PRINT
160 PRINT"FIFTY (50) IS THE UPPER LIMIT OF TEST UNITS AND TEST TIME IS EXPRESSED
 AS A"
170 PRINT"FRACTION OF THE CHARACTERISTIC LIFE, ETA."
180 PRINT"          RATIO = (TEST TIME)/(CHARACTERISTIC LIFE)"
190 PRINT"                              OR"
200 PRINT"           TEST TIME = RATIO * CHARACTERISTIC LIFE":PRINT
210 PRINT"INPUT THE WEIBULL SLOPE BETA (BETA <=5.0 ONLY) FOR THE FAILURE MODE";:
INPUT BETA
220 PRINT"INPUT THE CHARACTERISTIC LIFE ETA";:INPUT ETA:GOTO 350
350 CLS:PRINT:PRINT"USUALLY A TEST PROGRAM IS DRIVEN BY A PRACTICAL LEVEL OF TES
T TIME WHICH IS VERY"
360 PRINT"EXPENSIVE.":PRINT
370 PRINT"MAKE AN ESTIMATE OF A REASONABLE TEST TIME, RECOGNIZING THAT AT LEAST
THREE (3)"
380 PRINT"UNITS OR MORE MUST EACH BE TESTED FOR THAT TIME":PRINT
390 PRINT"INPUT TEST HOURS";:INPUT TESTHOURS:PRINT
400 RATIO=TESTHOURS/ETA:PRINT"RATIO =";RATIO,:PRINT"BETA =";BETA
410 PRINT
1000 PRINT"NOW CHOOSE THE NEAREST VALUE OF THE WEIBULL SLOPE BETA AND RATIO OF T
EST TIME"
1010 PRINT"TO THE CHARACTERISTIC LIFE THAT IS IN THE FOLLOWING TABLE.  MAKE A NO
TE OF THE"
1020 PRINT"SAMPLE SIZE FROM THE TABLE.":PRINT:PRINT
1050 PRINT"PRESS ENTER TO CONTINUE";:INPUT S$:IF S$="" THEN 1490
1490 CLS:PRINT"                         BETA"
```

```
1500 PRINT"RATIO  0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0"
1520 PRINT"0.01    24    !!    !!    !!    !!    !!    !!    !!    !!    !!"
1530 PRINT"0.02    17    !!    !!    !!    !!    !!    !!    !!    !!    !!"
1540 PRINT"0.03    14    !!    !!    !!    !!    !!    !!    !!    !!    !!"
1550 PRINT"0.04    12    !!    !!    !!    !!    !!    !!    !!    !!    !!"
1560 PRINT"0.05    11    47    !!    !!    !!    !!    !!    !!    !!    !!"
1570 PRINT"0.06    10    39    !!    !!    !!    !!    !!    !!    !!    !!"
1580 PRINT"0.07     9    33    !!    !!    !!    !!    !!    !!    !!    !!"
1590 PRINT"0.08     9    29    !!    !!    !!    !!    !!    !!    !!    !!"
1600 PRINT"0.09     8    26    !!    !!    !!    !!    !!    !!    !!    !!"
1610 PRINT"0.10     8    24    !!    !!    !!    !!    !!    !!    !!    !!"
1620 PRINT"0.20     6    12    26    !!    !!    !!    !!    !!    !!    !!"
1630 PRINT"0.30     5     8    15    26    47    !!    !!    !!    !!    !!"
1640 PRINT"0.40     4     6    10    15    23    36    !!    !!    !!    !!"
1650 PRINT"0.50     4     5     7    10    14    19    27    37    !!    !!"
1660 PRINT"0.60     3     4     5     7     9    11    14    18    23    30"
1670 PRINT"0.70     3     4     4     5     6     7     9    10    12    14"
1680 PRINT"0.80     3     3     4     4     5     5     6     6     7     8"
1690 PRINT"0.90     3     3     3     3     3     4     4     4     4     4"
1700 PRINT"1.00     3     3     3     3     3     3     3     3     3     3"
1720 PRINT"  !! INDICATES SAMPLE SIZE EXCEEDS 50 - INPUT 99 FOR SAMPLE SIZE"
1740 PRINT"           BETA=";BETA;"        RATIO=";RATIO
1750 PRINT"PRINT SCREEN FOR HARD COPY OF THE TABLE.  INPUT THE SAMPLE SIZE FROM
THE TABLE";:INPUT SS:GOTO 4990
2000 CLS:PRINT"                              BETA"
2010 PRINT"SAMPLE"
2020 PRINT" SIZE    0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0"
2030 PRINT"   3    .589  .767  .838  .876  .900  .916  .927  .936  .943  .948"
2040 PRINT"   4    .331  .576  .692  .759  .802  .832  .854  .871  .884  .895"
2050 PRINT"   5    .212  .460  .596  .679  .733  .772  .801  .824  .842  .856"
2060 PRINT"   6    .147  .384  .528  .619  .682  .727  .761  .787  .808  .826"
2070 PRINT"   7    .108  .329  .477  .574  .641  .690  .728  .757  .781  .801"
2080 PRINT"   8    .083  .288  .436  .536  .608  .660  .701  .732  .758  .780"
2090 PRINT"   9    .065  .256  .403  .506  .580  .635  .677  .711  .739  .761"
2100 PRINT"  10    .053  .230  .376  .480  .556  .613  .657  .693  .722  .745"
2110 PRINT"  12    .037  .192  .333  .438  .517  .577  .624  .662  .693  .719"
2120 PRINT"  14    .027  .164  .300  .406  .486  .548  .597  .637  .670  .697"
2130 PRINT"  16    .021  .144  .275  .379  .461  .524  .575  .616  .650  .679"
2140 PRINT"  18    .016  .128  .254  .358  .439  .504  .556  .598  .633  .663"
2150 PRINT"  20    .013  .115  .237  .339  .421  .486  .539  .582  .619  .649"
2160 PRINT"  25    .008  .092  .204  .303  .385  .452  .506  .551  .589  .621"
2170 PRINT"  30    .006  .077  .181  .277  .358  .425  .480  .526  .565  .598"
2180 PRINT"  40    .003  .058  .149  .240  .319  .386  .442  .490  .530  .565"
2190 PRINT"  50    .002  .046  .128  .215  .292  .358  .415  .463  .505  .540"
2195 PRINT"          BETA=";BETA;"        SAMPLE SIZE=";SS
2200 PRINT"PRINT SCREEN FOR HARD COPY OF TABLE.  INPUT TEST HOUR RATIO FROM TABL
E";:INPUT RATIO:GOTO 7200
4990 CLS:PRINT"                    SAMPLE SIZE=";SS:PRINT:PRINT
5000 PRINT"IF A REASONABLE RATIO OF TEST TIME TO ETA HAS RESULTED IN AN UNREASON
ABLE"
5010 PRINT"SAMPLE SIZE (OR A SAMPLE SIZE OF OVER FIFTY, INDICATED BY !!) YOU SHO
ULD NOW"
5020 PRINT"MAKE ANOTHER ESTIMATE OF TEST HOURS OR OPT FOR ANOTHER METHOD OF TEST
 PLAN"
5021 PRINT"DETERMINATION.":PRINT
5030 PRINT"PLEASE CHOOSE FROM THE FOLLOWING OPTIONS:":PRINT
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5035 IF SS=<50 GOTO 5100
5036 PRINT"******* SINCE SAMPLE SIZE IS";SS;"CHOOSE ONLY OPTION 2 OR 3 *******":
PRINT:PRINT
5040 FOR I=1 TO 12:BEEP:NEXT I
5045 PRINT"TO CONTINUE PRESS ENTER";:INPUT D$:IF D$="" THEN 5100
5100 PRINT"              1. DISPLAY THE TEST PLAN FOR CURRENT SAMPLE SIZE OF";SS
:PRINT
5110 PRINT"              2.  MAKE ANOTHER ESTIMATE OF TEST HOURS.":PRINT
5120 PRINT"              3.  USE ALTERNATE TEST PLAN METHOD.":PRINT:PRINT
5130 PRINT"INPUT OPTION NUMBER FROM THE ABOVE LIST.";:INPUT N
5140 ON N GOTO 5500,390,7000
5500 CLS:PRINT:PRINT:PRINT:PRINT"THE TEST PLAN CONSISTS OF THE FOLLOWING:":PRINT
:PRINT
5510 PRINT"                 SAMPLE SIZE IS";SS:PRINT
5520 PRINT"                 TEST HOURS ARE";TESTHOURS:PRINT:PRINT
5530 PRINT"IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE FAILURE
MODE WHERE":PRINT
5540 PRINT"                    BETA =";BETA;"  AND   ETA =";ETA:PRINT
5550 PRINT"HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED."
5560 PRINT "THE TEST TIME IS";RATIO*100;"PERCENT OF THE CHARACTERISTIC LIFE OF";
ETA;"HOURS."
5700 LPRINT:LPRINT:LPRINT:LPRINT"THE TEST PLAN CONSISTS OF THE FOLLOWING:":LPRIN
T:LPRINT
5710 LPRINT"                SAMPLE SIZE IS";SS:LPRINT
5720 LPRINT"                TEST HOURS ARE";TESTHOURS:LPRINT:LPRINT
5730 LPRINT"IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE FAILURE
 MODE WHERE":LPRINT
5740 LPRINT"                   BETA =";BETA;"  AND   ETA =";ETA:LPRINT
5750 LPRINT"HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED."
5760 LPRINT"THE TEST TIME IS";RATIO*100;"PERCENT OF THE CHARACTERISTIC LIFE OF";
ETA;"HOURS."
5900 FOR I=1 TO 8:LPRINT:NEXT I
5910 GOTO 29500
6000 END
7000 CLS:PRINT:PRINT:PRINT:PRINT"THE ALTERNATE TEST PLAN METHOD REQUIRES THE INP
UT OF A REASONABLE NUMBER OF"
7010 PRINT"UNITS FOR TEST (SAMPLE SIZE) AND THE SELECTION OF A TEST HOUR RATIO F
ROM THE "
7020 PRINT"FOLLOWING TABLE.  MAKE AN ESTIMATE OF A REASONABLE SAMPLE SIZE";:INPU
T SS:PRINT
7030 PRINT"NOW CHOOSE THE NEAREST VALUE OF THE WEIBULL SLOPE BETA AND THE SAMPLE
 SIZE YOU"
7040 PRINT"JUST ESTIMATED AND THEN NOTE THE CORRESPONDING TEST HOUR RATIO.":PRIN
T
7080 PRINT"PRESS ENTER TO CONTINUE";:INPUT S$:IF S$="" THEN 2000
7200 CLS:PRINT:PRINT:PRINT:PRINT"THE TEST PLAN NOW CONSISTS OF THE FOLLOWING:":P
RINT:PRINT
7210 PRINT"                 SAMPLE SIZE IS";SS:PRINT
7220 PRINT"                 TEST HOURS ARE";RATIO*ETA:PRINT:PRINT
7230 PRINT"IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE FAILURE
MODE WHERE":PRINT
7240 PRINT"                   BETA =";BETA;"  AND   ETA =";ETA:PRINT
7250 PRINT"HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED."
7260 PRINT"THE TEST TIME IS";RATIO*100;"PERCENT OF THE CHARACTERISTIC LIFE OF";E
TA;"HOURS."
7500 LPRINT:LPRINT:LPRINT:LPRINT"THE TEST PLAN NOW CONSISTS OF THE FOLLOWING:":L
PRINT:LPRINT
```

```
7510 LPRINT"                    SAMPLE SIZE IS";SS:LPRINT
7520 LPRINT"                    TEST HOURS ARE";RATIO*ETA:LPRINT:LPRINT
7530 LPRINT"IF ALL THE SAMPLES SURVIVE THE TEST WITHOUT FAILURE THEN THE FAILURE
 MODE WHERE":LPRINT
7540 LPRINT"                     BETA =";BETA;"   AND   ETA =";ETA:PRINT
7550 LPRINT"HAS BEEN EITHER ELIMINATED OR SIGNIFICANTLY IMPROVED."
7560 LPRINT"THE TEST TIME IS";RATIO*100;"PERCENT OF THE CHARACTERISTIC LIFE OF";
ETA;"HOURS."
7570 FOR I=1 TO 8:LPRINT:NEXT I:GOTO 29500
8000 END
19490 LPRINT"                                  BETA"
19500 LPRINT"RATIO  0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0"
19505 LPRINT"       ------------------------------------------------------------"
19520 LPRINT"0.01   24    **    **    **    **    **    **    **    **    **"
19530 LPRINT"0.02   17    **    **    **    **    **    **    **    **    **"
19540 LPRINT"0.03   14    **    **    **    **    **    **    **    **    **"
19550 LPRINT"0.04   12    **    **    **    **    **    **    **    **    **"
19560 LPRINT"0.05   11    47    **    **    **    **    **    **    **    **"
19570 LPRINT"0.06   10    39    **    **    **    **    **    **    **    **"
19580 LPRINT"0.07    9    33    **    **    **    **    **    **    **    **"
19590 LPRINT"0.08    9    29    **    **    **    **    **    **    **    **"
19600 LPRINT"0.09    8    26    **    **    **    **    **    **    **    **"
19610 LPRINT"0.10    8    24    **    **    **    **    **    **    **    **"
19620 LPRINT"0.20    6    12    26    **    **    **    **    **    **    **"
19630 LPRINT"0.30    5     8    15    26    47    **    **    **    **    **"
19640 LPRINT"0.40    4     6    10    15    23    36    **    **    **    **"
19650 LPRINT"0.50    4     5     7    10    14    19    27    37    **    **"
19660 LPRINT"0.60    3     4     5     7     9    11    14    18    23    30"
19670 LPRINT"0.70    3     4     4     5     6     7     9    10    12    14"
19680 LPRINT"0.80    3     3     4     4     5     5     6     6     7     8"
19690 LPRINT"0.90    3     3     3     3     3     4     4     4     4     4"
19700 LPRINT"1.00    3     3     3     3     3     3     3     3     3     3"
19720 LPRINT"  ** INDICATES SAMPLE SIZE EXCEEDS 50"
20000 LPRINT:LPRINT:LPRINT:GOTO 29000
29000 LPRINT"                                   BETA"
29010 LPRINT"SAMPLE"
29020 LPRINT" SIZE    0.5   1.0   1.5   2.0   2.5   3.0   3.5   4.0   4.5   5.0"
29025 LPRINT"        ------------------------------------------------------------
"
29030 LPRINT"   3    .589  .767  .838  .876  .900  .916  .927  .936  .943  .948"
29040 LPRINT"   4    .331  .576  .692  .759  .802  .832  .854  .871  .884  .895"
29050 LPRINT"   5    .212  .460  .596  .679  .733  .772  .801  .824  .842  .856"
29060 LPRINT"   6    .147  .384  .528  .619  .682  .727  .761  .787  .808  .826"
29070 LPRINT"   7    .108  .329  .477  .574  .641  .690  .728  .757  .781  .801"
29080 LPRINT"   8    .083  .288  .436  .536  .608  .660  .701  .732  .758  .780"
29090 LPRINT"   9    .065  .256  .403  .506  .580  .635  .677  .711  .739  .761"
29100 LPRINT"  10    .053  .230  .376  .480  .556  .613  .657  .693  .722  .745"
29110 LPRINT"  12    .037  .192  .333  .438  .517  .577  .624  .662  .693  .719"
29120 LPRINT"  14    .027  .164  .300  .406  .486  .548  .597  .637  .670  .697"
29130 LPRINT"  16    .021  .144  .275  .379  .461  .524  .575  .616  .650  .679"
29140 LPRINT"  18    .016  .128  .254  .358  .439  .504  .556  .598  .633  .663"
29150 LPRINT"  20    .013  .115  .237  .339  .421  .486  .539  .582  .619  .649"
29160 LPRINT"  25    .008  .092  .204  .303  .385  .452  .506  .551  .589  .621"
29170 LPRINT"  30    .006  .077  .181  .277  .350  .425  .480  .526  .565  .598"
29180 LPRINT"  40    .003  .058  .149  .240  .319  .386  .442  .498  .530  .565"
29190 LPRINT"  50    .002  .046  .128  .215  .292  .358  .415  .463  .505  .540"
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```
29195 FOR Q=1 TO 8:LPRINT:NEXT Q
29200 CHAIN "WEIBER"
29500 PRINT:PRINT:PRINT"DO YOU HAVE ANOTHER ANALYSIS TO RUN - (Y) OR (N)  ";:INP
UT A$
29510 CLS
29511 K=K+1
29520 IF A$="N" THEN 29600
29530 IF A$="Y" THEN 10
29540 CLS:GOTO 29500
29600 CLS:PRINT"WOULD YOU LIKE A HARD COPY OF THE TABLES USED IN THIS CODE";:INP
UT F$:IF F$="Y" THEN 19490 ELSE IF F$="N" THEN 29200
29999 END
30000 CLS:PRINT"SAVING ZOFAILSB ON DISK B":SAVE "B:ZOFAILSB":END
```

```
5     CLS
6     PRINT:PRINT
10    PRINT"                PROGRAM TO GENERATE A NON-ZERO FAILURE TEST PLAN"
20    PRINT"                      SAMPLE SIZE REQUIRED FOR GIVEN TEST TIME"
30    PRINT"                        WRITTEN BY JAMES L. BYERS, CODE 6052"
40    PRINT"                           NAVAL AIR DEVELOPMENT CENTER"
50    PRINT"                              WARMINSTER, PA 18974"

60    PRINT:PRINT:PRINT
100   LPRINT:LPRINT
110   LPRINT"                PROGRAM TO GENERATE A NON-ZERO FAILURE TEST PLAN"
120   LPRINT"                      SAMPLE SIZE REQUIRED FOR GIVEN TEST TIME"
130   LPRINT"                        WRITTEN BY JAMES L. BYERS, CODE 6052"
140   LPRINT"                           NAVAL AIR DEVELOPMENT CENTER"
150   LPRINT"                              WARMINSTER, PA 18974"

160   LPRINT:LPRINT:LPRINT
200  PRINT"THESE TEST PLANS WILL HAVE THE FOLLOWING STRUCTURE:":PRINT
210  PRINT"         A.  PUT N ITEMS ON TEST FOR T HOURS (CYCLES) EACH."
220  PRINT"         B.  WHEN AN ITEM ON TEST FAILS, IT IS NOT REPAIRED."
230  PRINT"         C.  IF R0 OR FEWER FAILURES OCCUR, THE TEST IS PASSED."
300  LPRINT"THESE TEST PLANS WILL HAVE THE FOLLOWING STRUCTURE:":PRINT
310  LPRINT"         A.  PUT N ITEMS ON TEST FOR T HOURS (CYCLES) EACH."
320  LPRINT"         B.  WHEN AN ITEM ON TEST FAILS, IT IS NOT REPAIRED."
330  LPRINT"         C.  IF R0 OR FEWER FAILURES OCCUR, THE TEST IS PASSED."
340  LPRINT:LPRINT
990  PRINT:PRINT
1000 PRINT"INPUT VALUE OF PROBABILITY OF PASSING TEST WITH ETA OF FAIL MODE."
1010 PRINT"THIS IS ONE MINUS THE PERCENT CONFIDENCE OF THE VALUE OF ETA - USUALL
Y 0.1"
1015 PRINT:PRINT"A0=";:INPUT A0
1050 PRINT:PRINT"INPUT VALUE OF PROBABILITY OF PASSING TEST WITH ETA DESIRED"
1060 PRINT"THIS IS THE PERCENT CONFIDENCE OF ETA DESIRED - USUALLY 0.9"
1065 PRINT:PRINT"A1=";:INPUT A1
1100 PRINT:PRINT"INPUT VALUE OF ETA FOR FAIL MODE";:INPUT E0
1150 PRINT:PRINT"INPUT VALUE OF ETA DESIRED";:INPUT E1
1200 PRINT:PRINT"INPUT NUMBER OF TEST HOURS FOR EACH TEST ARTICLE";:INPUT T
1250 PRINT:PRINT"INPUT VALUE OF BETA FOR FAIL MODE";:INPUT B
1260 CLS
1261 LPRINT:LPRINT
1264 LPRINT"A0 =";A0,"A1 =";A1,"ETA0 =";E0,"ETA1 =";E1,"TEST HOURS =";T,"BETA ="
;B
1290 REM R0=0
1291 R(0)=0:R(1)=1:R(2)=2:R(3)=3:R(4)=4:R(5)=5
1300 P0=1-EXP(-((T/E0)^B))
1350 P1=1-EXP(-((T/E1)^B))
1400 R0=0
1410 CLS
1450 FOR N0=1 TO 100
1500 G0=(1-P0)^N0
1550 PRINT"A0=";A0,"G0=";G0,"N0=";N0
1590 REM
1591 DIF=G0-A0
1592 IF DIF>.011 THEN 1650 ELSE 1660
1600 PRINT"ARE A0 AND G0 EQUAL OR CLOSE ENOUGH, (Y) OR (N)";:INPUT E$:IF E$="Y"
THEN 1660:IF E$="N" GOTO 1650
1610 IF E$<> "N" THEN 1590
```

```
1650 NEXT N0
1660 A0(0)=A0:G0(0)=G0:N0(0)=N0
1661 PRINT:PRINT:PRINT"          PRESS  F5  KEY TO CONTINUE"
1662 STOP
1665 CLS
1700 FOR N1=1 TO 100
1750 G1=(1-P1)^N1
1800 PRINT"A1=";A1,"G1=";G1,"N1=";N1
1810 DIF=G1-A1
1820 IF DIF>.011 THEN 1900 ELSE 1902
1850 PRINT"ARE A1 AND G1 EQUAL OR CLOSE ENOUGH, (Y) OR (N)";:INPUT E$:IF E$="Y"
THEN 1910:IF E$="N" THEN 1900
1860 IF E$<> "N" THEN 1850
1900 NEXT N1
1902 M=(N0*P0)/(N1*P1):PRINT M
1905 N=P0/P1:PRINT N
1910 A1(0)=A1:G1(0)=G1:N1(0)=N1:M(0)=M
1911 PRINT"          PRESS  F5  TO CONTINUE"
1912 STOP
2050 IF M=<N GOTO 6900
2100 IF M>N GOTO 2160
2140 CLS
2150 REM R0=1
2151 R(1)=1
2160 CLS
2200 FOR N0=1 TO 100
2250 G0=(1-P0)^N0+N0*P0*(1-P0)^(N0-1)
2300 PRINT"A0=";A0,"G0=";G0,"N0=";N0
2310 DIF=G0-A0
2320 IF DIF>.011 THEN 2400 ELSE 2410
2350 PRINT"ARE A0 AND G0 EQUAL OR CLOSE ENOUGH, (Y) OR (N)";:INPUT E$:IF E$="Y"
THEN 2410:IF E$="N" THEN 2400
2360 IF E$<> "N" THEN 2350
2400 NEXT N0
2410 A0(1)=A0:G0(1)=G0:N0(1)=N0
2411 PRINT"          PRESS  F5  TO CONTINUE"
2412 STOP
2420 CLS
2450 FOR N1=1 TO 100
2500 G1=(1-P1)^N1+N1*P1*(1-P1)^(N1-1)
2550 PRINT"A1=";A1,"G1=";G1,"N1=";N1
2560 DIF=G1-A1
2570 IF DIF>.011 THEN 2606 ELSE 2610
2600 PRINT"ARE A1 AND G1 EQUAL OR CLOSE ENOUGH, (Y) OR (N)";:INPUT E$:IF E$="Y"
THEN 2660:IF E$="N" THEN 2650
2605 IF E$<> "N" THEN 2600
2606 NEXT N1
2610 M=(N0*P0)/(N1*P1):PRINT M
2620 N=P0/P1:PRINT N
2660 A1(1)=A1:G1(1)=G1:N1(1)=N1:M(1)=M
2662 PRINT"          PRESS  F5  TO CONTINUE"
2665 STOP
2800 IF M=<N THEN 6900
2850 IF M>N GOTO 2910
2900 REM R0=2
2901 R(2)=2
2910 CLS
```

```
2950 CLS
2960 FOR N0=1 TO 100
3000 G0=(1-P0)^N0+N0*P0*(1-P0)^(N0-1)+(N0*(N0-1)/2)*P0^2*(1-P0)^(N0-2)
3010 PRINT"A0=";A0,"G0=";G0,"N0=";N0
3050 DIF=G0-A0
3060 IF DIF>.011 THEN 3150 ELSE 3160
3100 PRINT"ARE A0 AND G0 EQUAL OR CLOSE ENOUGH, (Y) OR (N)";:INPUT E$:IF E$="Y"
THEN 3160:IF E$="N" THEN 3150
3110 IF E$<> "N" THEN 3100
3150 NEXT N0
3160 A0(2)=A0:G0(2)=G0:N0(2)=N0
3161 PRINT"              PRESS  F5  TO CONTINUE"
3165 STOP
3170 CLS
3200 FOR N1=1 TO 100
3250 G1=(1-P1)^N1+N1*P1*(1-P1)^(N1-1)+(N1*(N1-1))/2*P1^2*(1-P1)^(N1-2)
3300 PRINT"A1=";A1,"G1=";G1,"N1=";N1
3310 DIF=G1-A1
3320 IF DIF>.011 THEN 3356 ELSE 3360
3350 PRINT"ARE A1 AND G1 EQUAL OR CLOSE ENOUGH, (Y) OR (N)";:INPUT E$:IF E$="Y"
THEN 3410:IF E$="N" THEN 3400
3355 IF E$<> "N" THEN 3350
3356 NEXT N1
3360 M=(N0*P0)/(N1*P1):PRINT M
3370 N=P0/P1:PRINT N
3410 A1(2)=A1:G1(2)=G1:N1(2)=N1:M(2)=M
3411 PRINT"           PRESS  F5  TO CONTINUE"
3415 STOP
3550 IF M=<N GOTO 6900
3600 IF M>N GOTO 3655
3650 REM R0=3
3651 R(3)=3
3655 CLS
3660 FOR N0=1 TO 100
3750 G0=(1-P0)^N0+N0*P0*(1-P0)^(N0-1)+(N0*(N0-1))/2*P0^2*(1-P0)^(N0-2)+(N0*(N0-1
)*(N0-2)/6)*(P0)^3*(1-P0)^(N0-3)
3800 PRINT"A0=";A0,"G0=";G0,"N0=";N0
3810 DIF=G0-A0
3820 IF DIF>.011 THEN 3900 ELSE 3910
3850 PRINT"ARE A0 AND G0 EQUAL OR CLOSE ENOUGH, (Y) OR (N)";:INPUT E$:IF E$="Y"
THEN 3910:IF E$="N" THEN 3900
3860 IF E$<> "N" THEN 3850
3900 NEXT N0
3910 A0(3)=A0:G0(3)=G0:N0(3)=N0
3911 PRINT"              PRESS  F5  TO CONTINUE"
3915 STOP
3920 CLS
3950 FOR N1=1 TO 100
4000 G1=(1-P1)^N1+N1*P1*(1-P1)^(N1-1)+(N1*(N1-1))/2*P1^2*(1-P1)^(N1-2)+(N1*(N1-1
)*(N1-2)/6)*(P1)^3*(1-P1)^(N1-3)
4050 PRINT"A1=";A1,"G1=";G1,"N1=";N1
4060 DIF=G1-A1
4070 IF DIF>.011 THEN 4106 ELSE 4110
4100 PRINT"ARE A1 AND G1 CLOSE ENOUGH (Y) OR (N)";:INPUT E$:IF E$="Y" THEN 4160:
IF E$="N" THEN 4150
4105 IF E$<> "N" THEN 4100
4106 NEXT N1
```

```
4110 M=(N0*P0)/(N1*P1):PRINT M
4120 N=P0/P1:PRINT N
4160 A1(3)=A1:G1(3)=G1:N1(3)=N1:M(3)=M
4170 PRINT"              PRESS  F5  TO CONTINUE"
4175 STOP
4300 IF M=<N GOTO 6900
4350 IF M>N GOTO 4402
4400 REM R0=4
4401 R(4)=4
4410 CLS
4450 FOR N0=1 TO 100
4500 G0=(1-P0)^N0+N0*P0*(1-P0)^(N0-1)+(N0*(N0-1))/2*P0^2*(1-P0)^(N0-2)+(N0*(N0-1
)/6)*(P0)^3*(1-P0)^(N0-3)+(N0*(N0-1)*(N0-2)*(N0-3)/24)*(P0)^4*(1-P0)^(N0-4)
4550 PRINT"A0=";A0,"G0=";G0,"N0=";N0
4560 DIF=G0-A0
4570 IF DIF>.011 THEN 4650 ELSE 4660
4600 PRINT"ARE A0 AND G0 CLOSE ENOUGH (Y) OR (N)";:INPUT E$:IF E$="Y" THEN 4660:
IF E$="N" THEN 4650
4610 IF E$<> "N" THEN 4600
4650 NEXT N0
4660 A0(4)=A0:G0(4)=G0:N0(4)=N0
4661 PRINT"             PRESS  F5  TO CONTINUE"
4665 STOP
4670 CLS
4700 FOR N1=1 TO 100
4750 G1=(1-P1)^N1+N1*P1*(1-P1)^(N1-1)+(N1*(N1-1))/2*P1^2*(1-P1)^(N1-2)+(N1*(N1-1
)*(N1-2)/6)*P1^3*(1-P1)^(N1-3)+(N1*(N1-1)*(N1-2)*(N1-3)/24)*P1^4*(1-P1)^(N1-4)
4800 PRINT"A1=";A1,"G1=";G1,"N1=";N1
4810 DIF=G1-A1
4820 IF DIF>.011 THEN 4856 ELSE 4860
4850 PRINT"ARE A1 AND G1 CLOSE ENOUGH (Y) OR (N)";:INPUT E$:IF E$="Y" THEN 4910:
IF E$="N" THEN 4900
4855 IF E$<> "N" THEN 4850
4856 NEXT N1
4860 M=(N0*P0)/(N1*P1):PRINT M
4870 N=P0/P1:PRINT N
4910 A1(4)=A1:G1(4)=G1:N1(4)=N1:M(4)=M
5050 IF M=<N GOTO 6900
5100 IF M>N GOTO 5152
5150 REM R0=5
5151 R(5)=5
5152 PRINT"              PRESS  F5  TO CONTINUE"
5155 STOP
5160 CLS
5200 FOR N0=1 TO 100
5250 G0=(1-P0)^N0+N0*P0*(1-P0)^(N0-1)+(N0*(N0-1))/2*P0^2*(1-P0)^(N0-2)+(N0*(N0-1
)*(N0-2)/6)*P0^3*(1-P0)^(N0-3)+(N0*(N0-1)*(N0-2)*(N0-3)/24)*P0^4*(1-P0)^(N0-4)+(
N0*(N0-1)*(N0-2)*(N0-3)*(N0-4)/120)*P0^5*(1-P0)^(N0-5)
5300 PRINT"A0=";A0,"G0=";G0,"N0=";N0
5310 DIF=G0-A0
5320 IF DIF>.011 THEN 5400 ELSE 5410
5350 PRINT"ARE A0 AND G0 CLOSE ENOUGH (Y) OR (N)";:INPUT E$:IF E$="Y" THEN 5410:
IF E$="N" THEN 5400
5360 IF E$<> "N" THEN 5350
5400 NEXT N0
5410 A0(5)=A0:G0(5)=G0:N0(5)=N0
5411 PRINT"              PRESS  F5  TO CONTINUE"
```

```
5415 STOP
5420 CLS
5450 FOR N1=1 TO 100
5500 G1=(1-P1)^N1+N1*P1*(1-P1)^(N1-1)+(N1*(N1-1))/2*P1^2*(1-P1)^(N1-2)+(N1*(N1-1
)*(N1-2)/6)*P1^3*(1-P1)^(N1-3)+(N1*(N1-1)*(N1-2)*(N1-3)/24)*P1^4*(1-P1)^(N1-4)+(
N1*(N1-1)*(N1-2)*(N1-3)*(N1-4)/120)*P1^5*(1-P1)^(N1-5)
5550 PRINT"A1=";A1,"G1=";G1,"N1=";N1
5560 DIF=G1-A1
5570 IF DIF>.011 THEN 5606 ELSE 5610
5600 PRINT"ARE A1 AND G1 CLOSE ENOUGH (Y) OR (N)";:INPUT E$:IF E$="Y" THEN 5660:
IF E$="N" THEN 5606
5605 IF E$<> "N" THEN 5600
5606 NEXT N1
5610 M=(N0*P0)/(N1*P1):PRINT M
5620 N=P0/P1:PRINT N
5660 A1(5)=A1:G1(5)=G1:N1(5)=N1:M(5)=M
5661 PRINT"                    PRESS  F5  TO CONTINUE"
5665 STOP
5800 IF M=<N GOTO 6900
5850 IF M>N GOTO 14990
6900 CLS
7100 PRINT"A0";TAB(11);"G0";TAB(22);"N0";TAB(33);"A1";TAB(44);"G1";TAB(55);"N1";
TAB(66);"M";TAB(77);"R0"
7150 FOR I=0 TO 5
7200 PRINT A0(I);TAB(11);G0(I);TAB(22);N0(I);TAB(33);A1(I);TAB(44);G1(I);TAB(55)
;N1(I);TAB(65);M(I);TAB(77);R(I)
7250 NEXT I
7300 PRINT:PRINT
7400 PRINT"NOW SELECT THE LAST TWO VALUES OF M AND COMPARE THEM WITH :":PRINT
7500 PRINT"  N=";P0/P1:PRINT:PRINT
7600 PRINT"THE FINAL VALUE OF N0 AND N1 ARE THE VALUES WHICH ARE IN THE ROW OF V
ARIABLES   THAT CONTAINS THE VALUE OF M CLOSEST TO THAT OF N - EITHER + OR -.:?
7800 PRINT"INPUT THESE VALUES OF N0 AND N1 AT THE PROMPTS":PRINT
7900 PRINT"INPUT N0:":INPUT N0
8000 PRINT"INPUT N1:":INPUT N1
8005 PRINT"INPUT R0:":INPUT R0
8010 PRINT:PRINT
8015 CLS
8020 PRINT"THE SAMPLE SIZE, EACH OF WHICH MUST BE TESTED FOR";T;"HOURS, IS":PRIN
T
8030 PRINT"                    SAMPLE SIZE =";INT(((N0+N1)/2+.5))
8031 PRINT:PRINT"IF";R0;"OR LESS FAILURES OCCUR THE TEST IS PASSED."
8050 LPRINT:LPRINT
8100 LPRINT"THE SAMPLE SIZE, EACH OF WHICH MUST BE TESTED FOR";T;"HOURS, IS:":LP
RINT
8200 LPRINT"                    SAMPLE SIZE =";INT(((N0+N1)/2+.5))
8231 LPRINT:LPRINT"IF";R0;"OR LESS FAILURES OCCUR THE TEST IS PASSED."
8240 PRINT:PRINT:LPRINT:LPRINT
8245 SAMPSIZE=INT((N0+N1)/2+.5)
8250 TOTESTHR=SAMPSIZE*T
8260 PRINT"MAXIMUM TOTAL TEST HOURS IF ALL TEST UNITS RUN W/O FAILURE =";TOTESTH
R;"HOURS
8270 LPRINT"MAXIMUM TOTAL TEST HOURS IF ALL TEST UNITS RUN W/O FAILURE =";TOTEST
HR;"HOURS
9000 PRINT:PRINT
9100 PRINT"DO YOU HAVE ANOTHER ANALYSIS TO DO (Y) OR (N)";:INPUT A$
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9200 IF A$="Y" THEN 9600
9300 IF A$="N" THEN 9500
9350 CLS:GOTO 9100
9500 CHAIN "WEIBER"
9600 CLS:GOTO 1000
14980 END
14990 PRINT"PROBLEM NOT SOLVEABLE ON THIS CODE."
29999 END
30000 CLS:PRINT"SAVING NZFTESTP (NON-ZERO-FAILURE TEST PLAN GENERATOR) ON DISK B
":SAVE "B:NZFTESTP"
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